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1967 REVIEW OF SOUND DIVISION PROGRAM

[redacted]

GROUP-3
Downgraded at 12 year intervals;
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UNITED STATES GOVERNMENT

Memorandum

7100-119

DATE: 20 August 2002

REPLY TO ATTN OF: Burton G. Hurdle (Code 7103)

SUBJECT: REVIEW OF REF (A) FOR DECLASSIFICATION

TO: Code 1221.1

REF: (a) "1967 Review of Sound Division Program" (U) NRL NO. 540163, (C) 1967

1. Reference (a) is a review of the program and performance of the Sound Division Program for 1967.

2. The technology and equipment of reference (a) have long been superseded. The current value of this paper is historical.

3. Based on the above, it is recommended that reference (a) be declassified and released with no restrictions.

Burton G. Hurdle

BURTON G. HURDLE
NRL Code 7103

CONCUR:

Edward R. Franchi 8/20/02

E.R. Franchi Date
Superintendent, Acoustics Division

CONCUR:

Tina Smallwood 8/21/02

Tina Smallwood Date
NRL Code 1221.1

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1967 REVIEW OF SOUND DIVISION PROGRAM

A. SCIENTIFIC PROGRAM

I. Mission

The mission of the Sound Division is to carry out research and development in acoustics that has certain or probable application to fleet needs. In view of the facts that this Laboratory is a research laboratory and the Systems Commands have laboratories of their own to carry out the major systems problems, Research and Development in the Sound Division of the Naval Research Laboratory logically emphasizes research.

II. Areas of Research

The areas of research are the major areas in underwater acoustics applicable to anti-submarine warfare. These include sound generation, sound propagation, and signal physics. Research in these areas is aimed primarily at acoustics applied to active sonar in anti-submarine warfare. The knowledge and techniques evolved have, in general, application also to other facets of the anti-submarine warfare mission and to other warfare missions.

III. Organization

In order to carry out the program, the Sound Division is organized as shown in Table I.

CODE	BRANCH	HEAD	AREA OF RESEARCH
5510	Acoustic Research	Dr. R. L. Steinberger	Research under controlled conditions
5520	Transducer	S. Hanish	Transducers, arrays, calibrating techniques
5530	Electronics	H. L. Peterson*	Signal physics -- long range
5550	Techniques	R. H. Mathes	Near-surface effects
5560	Propagation	A. T. McClinton	Signal physics -- short and medium range

* Acting

TABLE I
Branch Heads and Major Branch Assignments

The branches range in size from 13 to 22. These figures include one clerical employee in each branch. The total number in branches is 80 out of a Division ceiling of 101 (other Division personnel will be accounted for under B -- Administrative Factors).

IV. Program

The program will be discussed, branch by branch, under the headings of Objectives, Productivity, and Future Plans. In view of the existence of a previous yearly Division report and Work Unit Summaries, objectives will be stated as briefly as possible. Productivity will cover accomplishments in the past year, and Future Plans will be up-dated from last year.

All reports contributing to productivity are listed in the Branch Review Boards review following the program discussion.

1. Objectives

In an effort to enhance the Navy's capability in Sonar, the Acoustic Research Branch singles out for study, specific acoustic situations which have not heretofore been described with sufficient experimental or mathematical precision. Currently there are five studies underway; (1) experimental confirmation of the relationship between the sound rays and the sound speed profile in the ocean; (2) precision measurement of sound speed and absorption in sea water and in other acoustic media of Sonar importance, as functions of pressure, temperature and salinity; (3) refined experimental measurement and mathematical confirmation of findings essential to a detailed description of acoustic reflection from special objects in water; (4) description of the forces incident to flow of water about submerged objects inducing vibrations which emit sound, and the physical description of the vortices in which the forces arise; (5) processes of information storage and retrieval ranging from the quality control of magnetic tape to instrumentation for automatic programming and data processing.

2. Productivity

a) Ocean Sound Propagation -- A final field trip under this problem was taken at about the time of last year's Division review. It was planned to devote all future efforts on this problem to analysis and reporting. This plan has been carried out. Data during the last field trip were taken with increased precision. One of the effects studied is the Lloyd mirror effect, which now can ~~not~~ be demonstrated with certainty. Fig. 1 represents data taken at 400 Hz. Each point on the curve represents the measurement of 1 data point. It will be noted that these data include points in the shadow zone. Such data are applicable to the Assured Range problem being carried out in another branch.

b) Ultrasonics -- In the past year instrumentation has been completed and put to use. Fig. 2 shows the values of sound speed in water which have been reported by various investigators over many years. The degree of uncertainty as measured by each investigator is shown by the indicated spread of values. The final value taken at 25°C and atmospheric pressure is obtained with NRL's new instrumentation and possesses much higher precision than the others, as indicated. The Bureau of Standards has accepted this value. Work is continuing with ocean

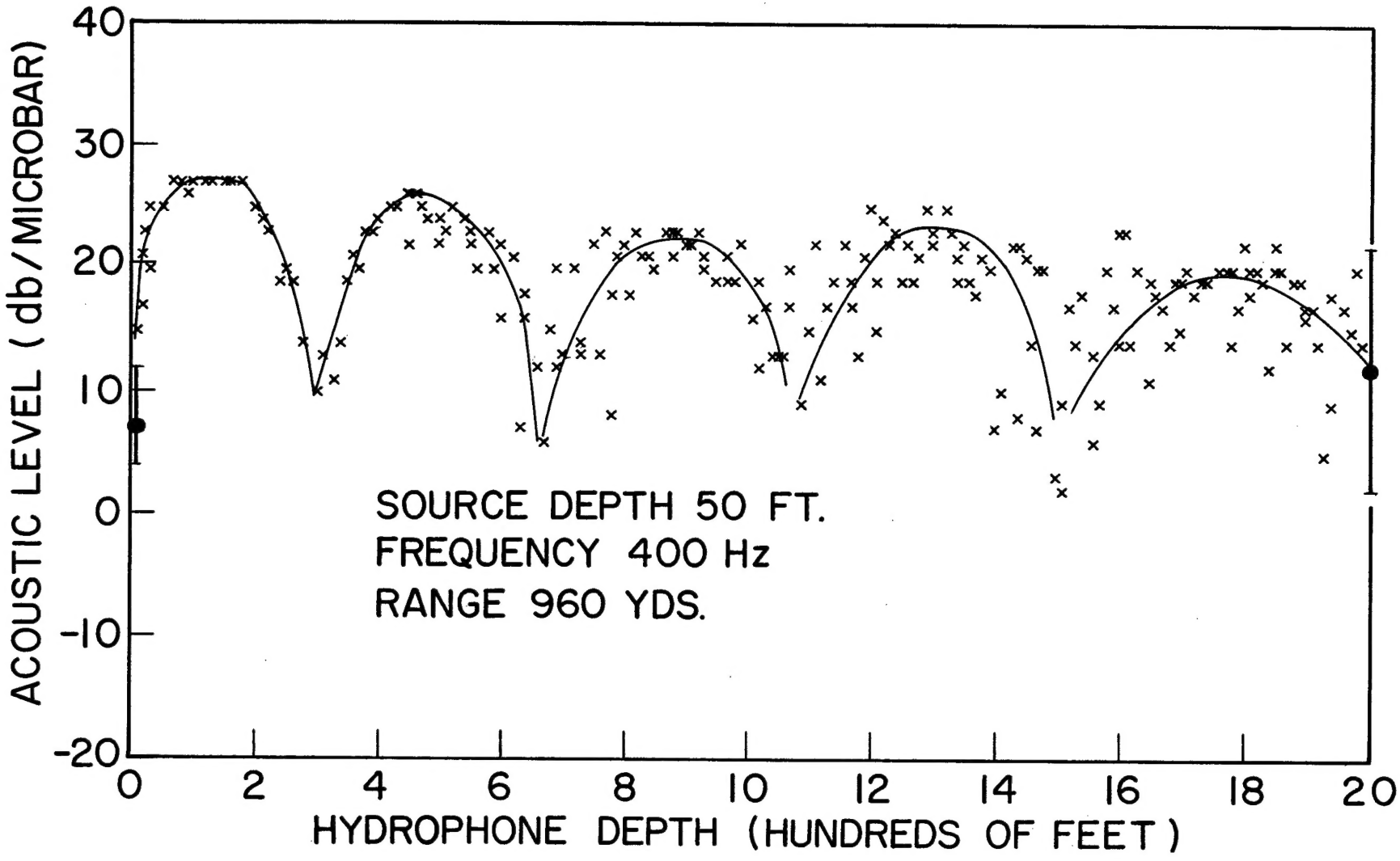
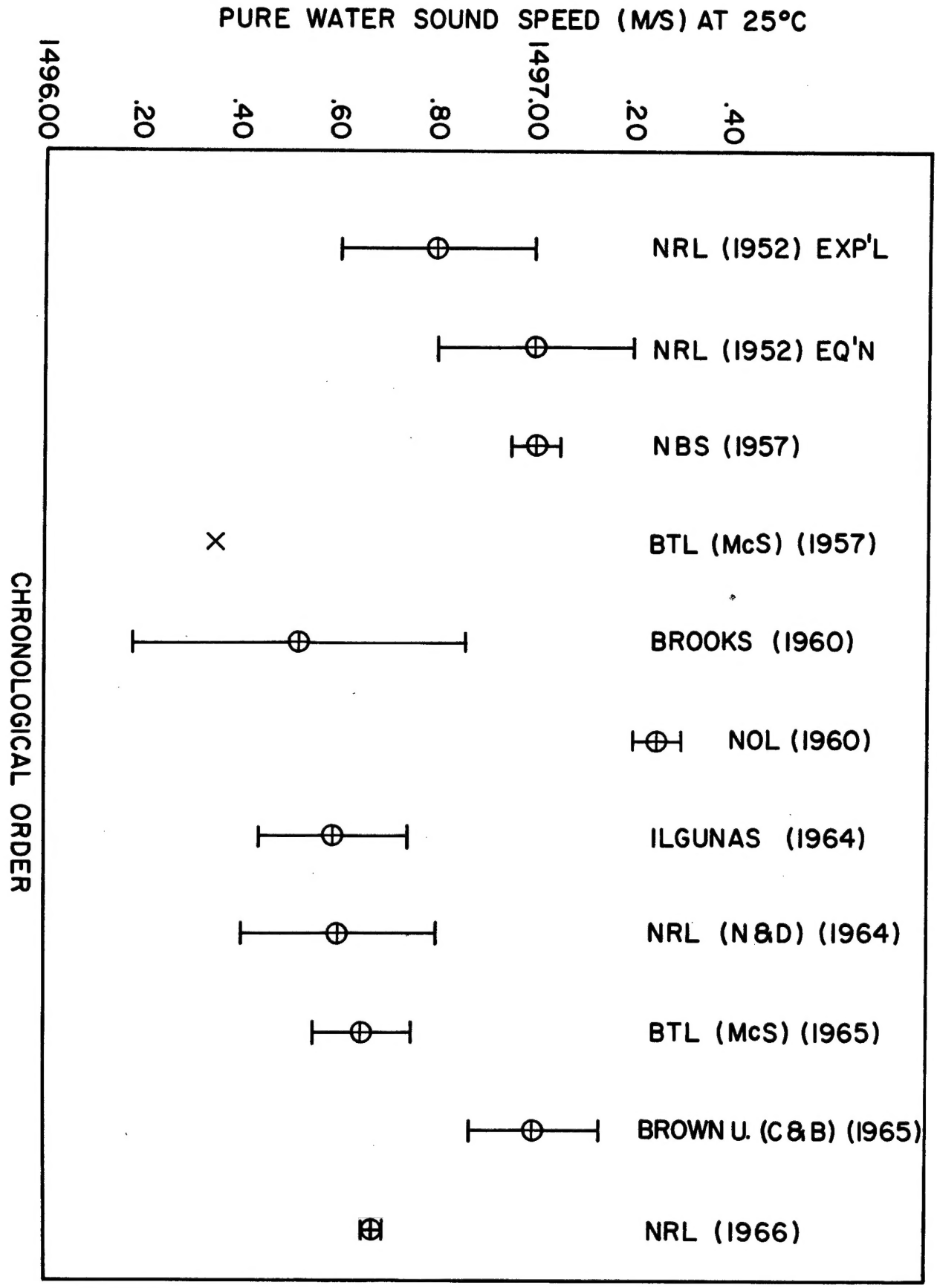


Fig. 1 -- LLOYD MIRROR EFFECT

Fig. 2 -- VALUES OF SOUND SPEED IN PURE WATER



water of various salinities and at various temperatures. A speed has been obtained for standard sea water at atmospheric pressure, 25°C and 35‰ salinity which is regarded as a preliminary measurement.

c) Microacoustics -- Work in the past year has accented back scattering from spheres of which the elasticity influences the result. Theory and experiment are in good accord as illustrated in Fig. 3.

d) Flow Acoustics -- Two accomplishments will be cited. The damping in a nickel alloy provided by the Naval Ordnance Laboratory has been measured. Cooperative effort with NOL is continuing in order to reach an understanding of the results and possibly to improve the results. It has been determined that the lift coefficient on a rod in an air stream lies between .2 and .5. From this, the force acting on the rod and the radiated sound energy can be calculated. As the vibration of the rod increases under excitation by the air stream, a point is reached where the vortex stream suddenly becomes coherent along the rod. Accompanying this is a jump in the force on the rod. Further increase in vibration amplitude appears to result in moderate increase in force with a linear relationship.

e) Naval Sound Recording -- Effort has been concentrated during the past year on providing a computer programmer for NRLTCF. This is now on order and the two men engaged in this work have taken a course in its use.

f) Sound Control and Measurement -- A recent intense activity has been aimed at acoustic parts of equipment for use in Viet Nam. This has required the Section Head to make several trips to Panama.

3. Future Plans

a) Ocean Sound Propagation -- It is planned to prepare one or two reports covering present analysis of data by the end of FY 68, and then to close out the problem. The scientific manpower (3 men), and the ONR general funds, should be shifted to other problems.

b) Ultrasonics -- The short-range future plans are first to acquire comprehensive data on sound speed in sea water at atmospheric pressure, second to extend data

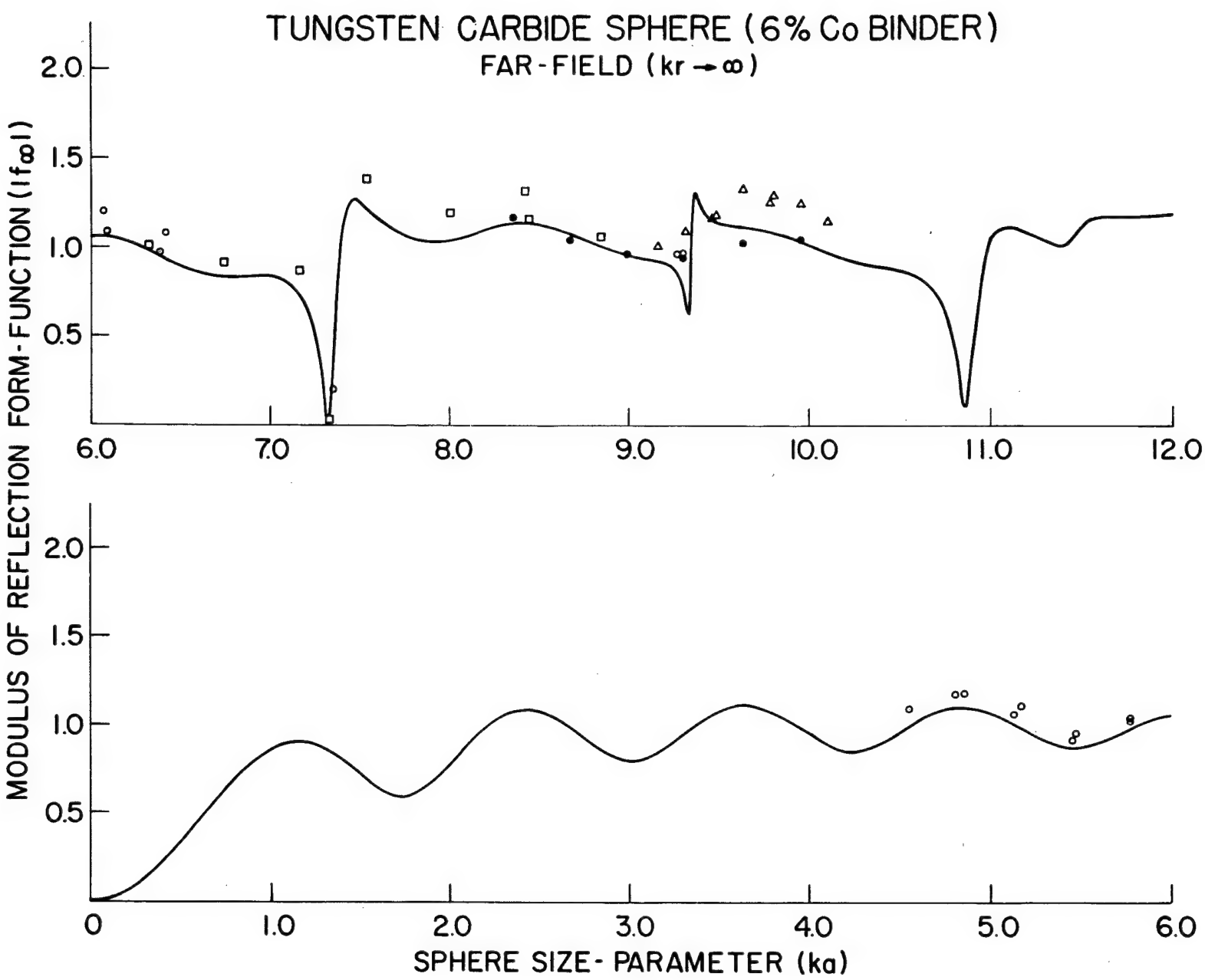


Fig. 3 -- BACK-SCATTERING FROM ELACTIC SPHERES

taking to a wide range of pressure up to 15,000 psi, third to determine absorption in sea water as a function of pressure.

c) Microacoustics -- This problem is expected to yield results on reflection from objects of different shapes, elastic constants, and dimensions.

d) Flow Acoustics -- Present efforts will be accelerated if the Section Head can be augmented by one qualified person. The interaction of turbulence and induced vibration will be studied in an effort to obtain a better model than the linear one so far developed. Means for avoiding coherence in vortices and thereby reducing generated noise may be found.

e) Naval Sound Recording -- The Section engaged in this work will continue along present lines until the computer program for NRLTCF has been adapted to the desired uses. This will include program writing. The effort will then turn back to problems of magnetic tape and problems of specialized recorders.

f) Sound Control and Measurement -- This problem is normally a modest effort including auditorium acoustics and measurements in the anechoic chamber. The Viet Nam problem will continue to receive attention, however, as long as required.

COMMITTEE REPORT ON THE PROGRESS OF THE SOUND DIVISION'S ACOUSTIC RESEARCH BRANCH

Committee Membership

The committee is composed of

Dr. H. L. Saxton, Chairman

Dr. G. P. Ohman

Mr. R. H. Mathes

Dr. R. L. Steinberger

The committee met on the afternoon of 18 April 1967 following the presentation of the progress by Dr. Steinberger and his Section Heads.

Nature of the Work

Most of the work of this Branch is basic research. All funds are ONR general in the 6.2 category.

Navy Needs

Underwater sound has found extensive application to antisubmarine warfare with respect to detection, classification, pinpointing, and attack. Because of the variability of the ocean and the difficulty of obtaining conclusive and adequate data at sea, many of the problems associated with sound propagation, and reflection, as well as problems involving noise generation, remain unsolved. The Navy urgently needs data which will aid in range prediction, relationships between range and time, propagation loss, and vibration generated noise resulting from own ships motion. It also needs means of quieting ships. It also need techniques for recording and analyzing data obtained toward these ends.

The various problems in the Branch are aimed at:

S01-01 Ocean Sound Propagation

Objective

To gain an understanding of the mechanisms of propagation loss, and of both spatial and temporal fluctuations.

S01-02 Ultrasonics

Objective

Determine sound speed accurately in pure water and ocean water over a wide range of temperatures and pressures. Determine also absorption of sound as a function of pressure, temperature, and salinity.

S01-04 Microacoustics

Objective

To carry out scale model studies of reflection from objects and to determine experimentally and theoretically the dependence of reflection patterns on shape, elasticity, and form.

S01-05 Flow Acoustics

Objective

To determine mechanisms of flow noise and techniques for reducing it or controlling its spectrual distribution.

S01-10 Naval Sound Recording

Objective

Attack all facets of energy storage, both analog and digital. To develope techniques for data processing in particular in relationship to transducer calibration data.

S01-11 Sound Control & Measurement

Objective

Solve problems on auditorium acoustics. Extend theory to open spaces in jungles.

It will be appreciated that all of these problems have direct application to ASW or other Navy missions.

Technical Program

All problems of the Branch are basic in nature with the exceptions of S01-10 and S01-11. All employ an experimental approach augmented by whatever theoretical support is required. Personnel have demonstrated their ability to cope with the theoretical problems involved.

S01-01, Ocean Sound Propagation is yielding more precise data than a year ago by virtue of more precise control of the ocean geometry. In the presentation, agreement of data with the predicted Lloyd Mirror effect was excellent. The ability of the group to extract from these data a reflection coefficient is commendable. The committee understands that analyses is being extended to all ranges up to 70,000 yards. It is understood that effects at about 3,000 to 10,000 yards will be particularly applicable to other problems in the Division.

S01-02, Ultrasonics is expected to amass a great deal of data in the next year the publication of which will be widely accepted and will inhance the prestige of NRL in this field. The review committee feels that the importance of this work

and the magnitude of the work will keep this problem active for some years to come.

S01-04, Microacoustics - This work is recognized as possessing an accuracy that is in access of that obtained by other activities. The approach being undertaken is quite extensive and progress appears rather slow. However, considering the precision of the work this is explainable. The Branch has made repeated efforts to obtain expanded facilities for this work. Two tanks were planned in A-59 to be procured as a part of MilCon development. This has not so far shown much promise of providing the facility. It is recommended that the smaller of the two requested tanks be obtained on problem funds in A-59 and that the Laboratory provide funding for same.

S01-05, Flow Acoustics - The progress on this problem has been retarded by shortage of personnel. In a preceding year, the Section Head was almost entirely divorced from the problem by involvement in the WOW Campaign, and during the past year his capable assistant has resigned. In spite of these difficulties, progress has been steady. The Section Head's capability has been recognized particularly by ONR which has called upon him for consultative services. The committee recommends a build up of effort in this area.

S01-10, Naval Sound Recording, and S01-11, Sound Control and Measurement - The work accomplishment of a group of two men on these two problems is impressive as is their versatility. They constitute a team of demonstrated ability to solve a variety of problems pertaining to recording and playback, and data processing quickly and reliably. There is room for expansion of this effort if the Laboratory can provide funding for this purpose.

Reporting

Reports of the last year are listed in Table 1.

Conclusions and Recommendations

a. The committee is assured of the Navy's need for this program.

b. The program is being prosecuted with thoroughness and with demonstrated scientific capability.

c. Ocean Sound Propagation should be phased out in about another year, while the efforts on both Flow Acoustics and Naval Sound Recording should be expanded.

d. Funding is adequate for the present level of work.

e. Personnel problems are not critical except in the Flow Acoustics Section where additional qualified help is urgently needed.

ACOUSTIC RESEARCH BRANCH
NRL REPORTS AND PAPERS

31 March 1967

Title	No. Pages	No. Tables	No. Figures	Comments
A.J. Rudgers, "Monostatic Reflection from Rigid Objects Defined by Quadric Surfaces," Journal of the Acoustical Society of America, Vol. 39, No. 2, February 1966, pp. 294-300.	7	1	8	A formula is derived which may be used to calculate reflection from convex quartic surfaces.
V.A. Del Grosso, "Systematic Errors in Ultrasonic Propagation Parameter Measurements - Part 3 - Sound Speed by Iterative Reflection-Interferometry," NRL Report 6409, March 1966.	164	82	37	The reports delineate the systematic errors inherent in measurement of sound wave phenomena in confined samples.
W.G. Neubauer and L.R. Dragonette, "Monostatic Reflection from a Rigid rectangular Plane," Journal of the Acoustical Society of America, March 1967.				Acoustic measurements in water of far field monostatic reflection from rectangular blocks correspond with an approximate theory to within 2% at normal incidence.
V.A. Del Grosso, "Problems in the Absolute Measurement of Sound Speed," Navy Journal of Underwater Acoustics, October 1966, and in the Proceedings of the ONR Sponsored Workshop on "The Direct Measurements of Sound Speeds in Sea Water."	16	6	12	Announcement was made that the latest NRL measurement of the speed of sound in pure water at 25°C is 1496.67 ± 0.02 meters per second.
G.H. Koopmann, "The Vortex Wakes of Vibrating Cylinders at Low Reynolds Numbers," to be published in the Journal of Fluid Mechanics, 1967.	30	0	16	The effect of the transverse motion of a cylinder on its natural vortex wake is examined. Conditions are established for which the vortex wake frequency is controlled by the driving frequency of the cylinder.
A.J. Rudgers, "Techniques for Numerically Evaluating the Formulae Describing Monostatic Reflection of Acoustic Waves by Elastic Spheres," NRL Report 6551, 1967 (in publication)	79	2	9	The report describes numerical methods by which the formulae that specify the acoustic field resulting from the scattering of an acoustic wave by an elastic sphere may be evaluated.
G.H. Koopmann, "On the Wind-Induced Vibrations of Circular Cylinders," Thesis for Catholic University, March 1967.	68	0	20	Flow studies of the three-dimensional vortex wake structure gives insight into the nature of the vortex shedding mechanism.

Table 1

Transducer Branch

1. Objectives

The Navy is faced with serious problems involving underwater sound transducers. Major problems are the elimination of uncontrolled interaction between transducer elements of an array and between an array and its ship hull environment; the devising of techniques for the practical calibration of large low-frequency transducers, first at calibration stations and then in situ on ships; and making transducer arrays operable at great depths in the ocean. The following problem objectives emphasize an attack on these problems.

a) Basic Radiation Theory -- In order to interpret and to reduce to useable form modern theories of acoustic radiation, the literature is reviewed, organized, and interpreted in book form written in a succession of reports constituting chapters. Since a lack of tables of functions required for acoustic radiation computations exists, tables of special wave functions are being computed and published.

b) Transducer Mathematical Models -- The development of mathematical models of important transducer types and arrays will enable Navy personnel to design with technical certainty modern large underwater sound transducers for long-range, deep-submergence, high-power applications, in a variety of environments.

In order to provide for the accurate calibration of the Navy's largest transducers, the theory of far-field calibration by near-field measurements is further developed.

c) Electroacoustic Modeling -- Techniques are evolved and constructions carried out on hydrophone lines and arrays to serve as large-size calibration instruments by Near Field methods. Deep-water arrays are developed and research on them is aimed at providing required directionality by bi-planar positioning of freeflooding magnetostriction pings. Research is carried out on scale models tested in the Acoustic Research Tank (ART) to confirm the validity and adequacy of methods of theoretical prediction. The experimental work with Near-Field Calibration Methods is carried out in natural lakes (Bugg Spring, Florida and Lake Seneca, New York).

2. Productivity

a) Basic Radiation Theory -- The first volume of Oblate Spheroidal Wave Function Tables has been completed and is printed (NRL Report 6472). This volume contains a tabulation of 68,700 entries including radial functions of the 1st and 2nd type and their derivatives. A second volume of the Oblate Spheroidal Wave Function Tables is completed and in print stage. Three volumes of the Prolate Spheroidal Wave Functions are completed with one printed as NRL Report 6502. A NRL Memorandum Report on the Theory of Transient Radiation was published March 1966. This report is the third report in a series of reports being compiled as a treatise on radiation theory.

b) Transducer Mathematical Models -- NRL has developed a mathematical model of the multi-element transducer array of variable reluctance dipole elements and written a computer program to determine its performance in the presence of acoustic interactions among array elements. This mathematical model has been used to study the possibility of making a broad-band transducer by altering the mechanical resonant frequencies, element by element, across an array.

NRL has also constructed a mathematical model of the 3-mass transducer element. Among the design parameters studied are the effects on performance arising from changing ratios of end mass to center mass, and changing coupling spring constants. The concept of "transfer function" has been introduced into this investigation and the corresponding zeros and poles accurately plotted on the complex impedance plane.

In a joint effort with a parallel project there has been developed a mathematical model of a Near-field Test and Calibration Array. Extensive computations based on this model have been used to design near field arrays for use in USA and in Great Britain.

c) Electroacoustic Modeling -- The near-field calibration array (NFCA No. 1) was launched at Bugg Spring, Florida. Fig. 4 shows a stage of this operation. The initial calibration measurements were completed. The elimination of two stainless steel coupling joints in each line reduced variations of the plane-wave region of the near field from ±2db to ±1db. Construction modification was then carried out. Calibration of the modified array at Bugg Spring has now been completed, and the array has been shipped to Seneca Lake.

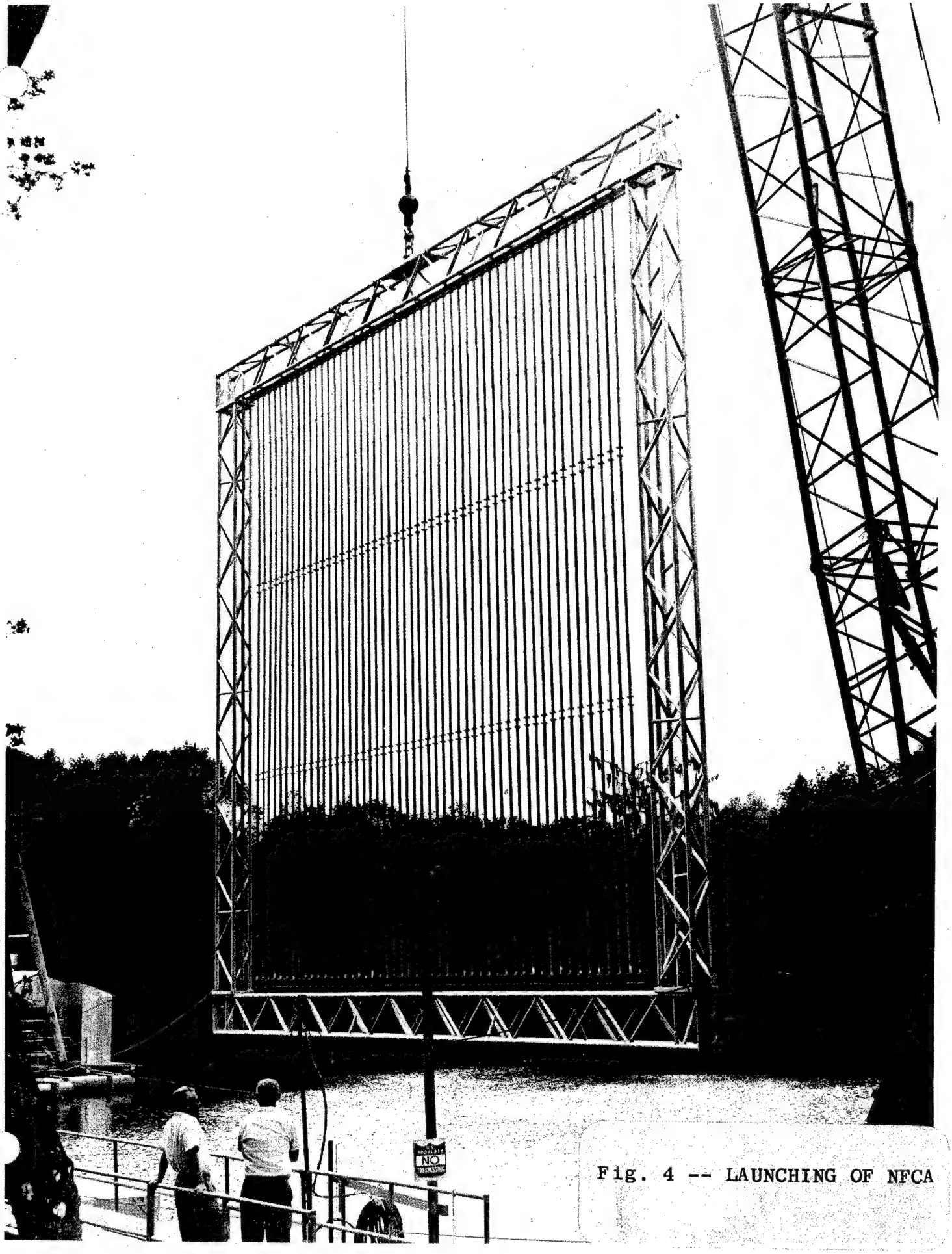


Fig. 4 -- LAUNCHING OF NFCA

Construction was completed on the 30' diameter Acoustic Research Tank (ART) and its enclosure. The electronic instrumentation of ART was then installed. Walkways and tracks across ART have been added. These appear in the view of the tank shown in Fig. 5.

Measurements made at Seneca Lake on a biplanar array of 24 full-scale, free-flooded, deep submergence, magnetostrictive ring transducers (Fig. 6) indicated a directional acoustic beam with a back lobe suppression of 21db and a mechanical Q in water of 2.1. However, minor lobes exist in the plane of the array. The design and construction of 100 free-flooded ring transducers for a scale-model array have been completed.

3. Future Plans

a) Basic Radiation Theory -- The work on the "Advances in Transducer Design Since World War II" will be continued with two new chapters scheduled for the coming year and completion scheduled for the end of FY 69. Work will be initiated in 1) multipole radiation, 2) advanced theory of a piston in a plane, and 3) creeping wave theory. Tabulations of Spheroidal wave functions will be carried out to completion. Statistical radiation and non-linear radiation will receive attention.

b) Transducer Mathematical Models -- The end product of the current program in mathematical modeling is a thoroughly digested set of parametric curves of sonar transducer behavior in the presence of a complicating environment arising from domes, ship hull, depth, etc.

Design of a mathematical model of a 3-dimensional transducer array simulating a submarine-mounted sonar accurately scaled from a selected current installation, will be carried out.

c) Electroacoustic Models -- Construction will be initiated of multi-element, underwater transducer arrays having classical shapes (planes, spheres, cylinders, spheriods). Theory will be checked against scale models in the Acoustic Tank (Building A-59). An interim report on NFCA No. 1 will be completed.

Modifications of the Lighter, the YC 1379, now at NRLTCF at Dresden, New York, on Seneca Lake require completion for handling the near-field calibration array (NFCA No. 1) installed in its support frame.

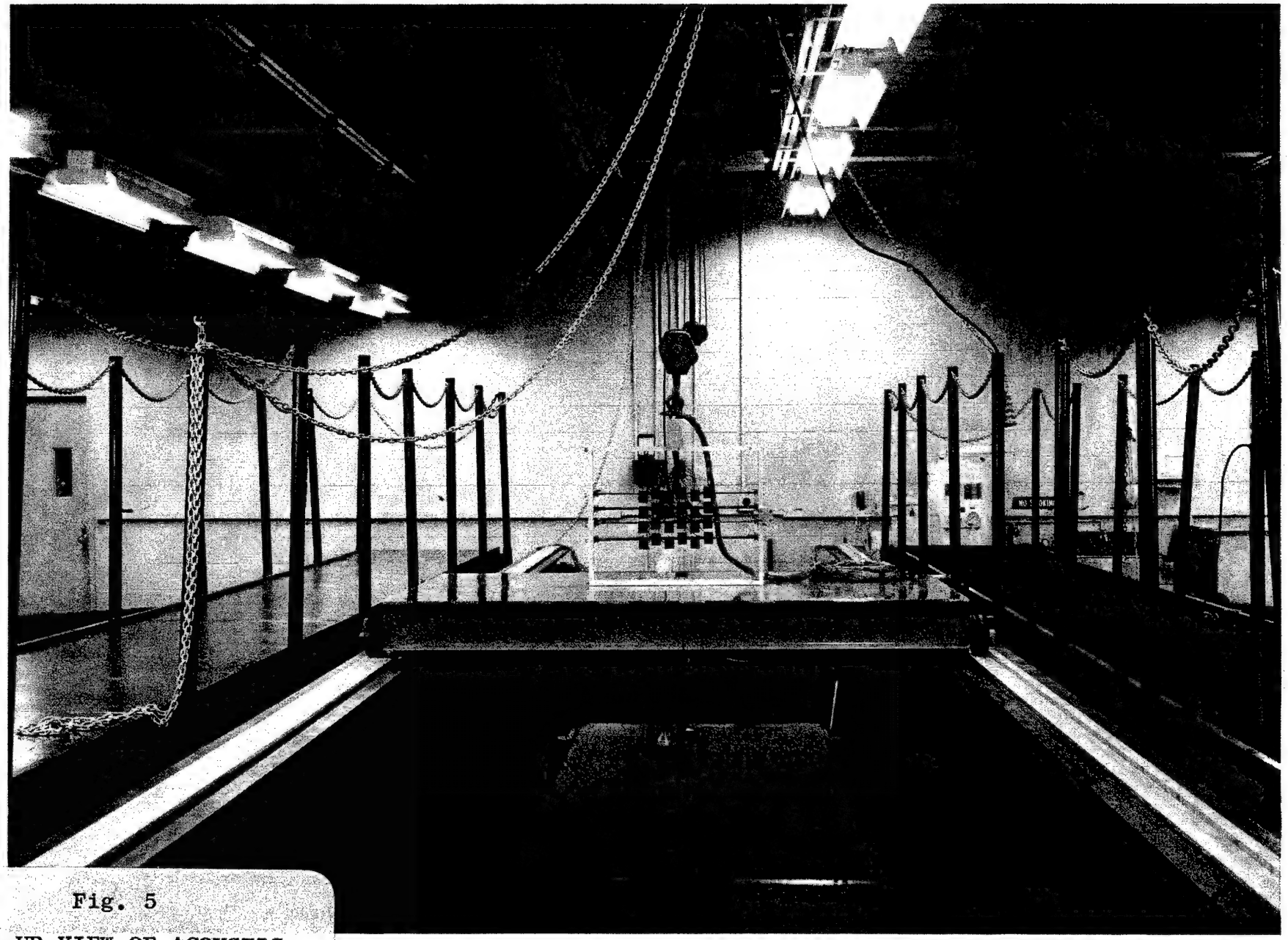


Fig. 5

CLOSE-UP VIEW OF ACOUSTIC RESEARCH TANK

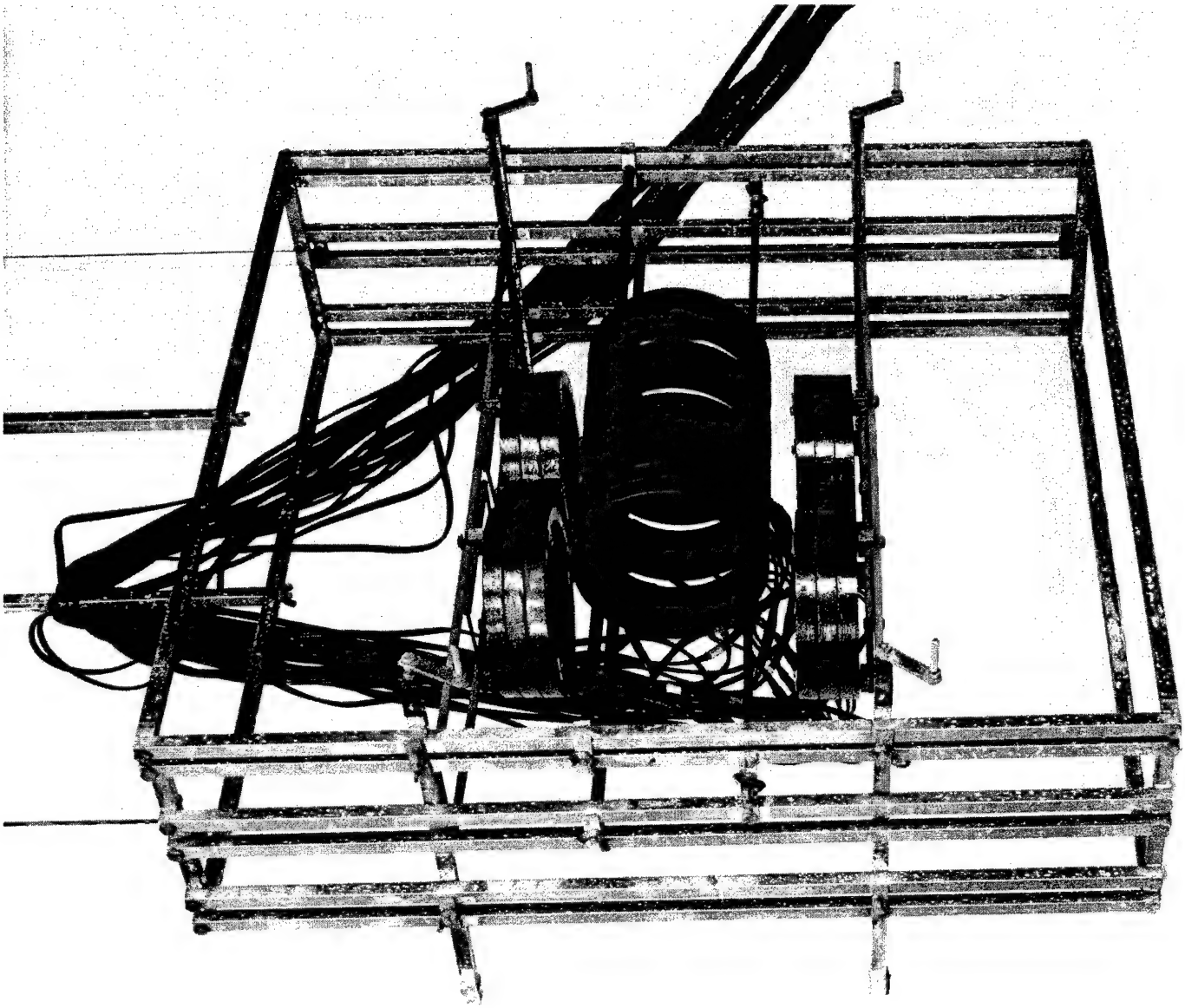


Fig. 6 -- BIPLANAR ARRAY

Ten spare 50-element columns (near-field shaded lines) for the NFCA No. 1 will be constructed.

The check-out program of far-field calibration measurements with the NFCA No. 1 on a series of directional beam transducers of various sizes from 1λ x 1λ to 7λ x 7λ will be initiated. Tests of the BQS-6 array using near-field techniques will be started.

A multi-element, planar transducer array model of 50 or less ADP crystal elements will be constructed for use in the Acoustic Research Tank for experimental studies of acoustic interactions between transducer elements.

REPORT OF THE REVIEW COMMITTEE FOR THE TRANSDUCER BRANCH SOUND DIVISION

General

The committee met on the afternoon of April 6 following a presentation of the Transducer Branch in the morning of the same day. The following committee members were present:

H. L. Saxton, Chairman
R. J. Bobber
A. T. McClinton
S. Hanish

Nature of the Work

The work of the branch consists largely of research both theoretical and experimental. The theoretical part of the work is supported by 6.1 funding. Experimental portion receives 6.2 funding from NAVSHIPS but is expected in the future to be supported by the same funding that supports the theoretical work. In addition to the foregoing research, the branch is involved in elaborate instrumentation for carrying out calibration techniques. The branch also performs services to the Laboratory, for the sponsors and their contractors by operating high pressure facilities.

Navy Need

The Navy needs long range detection and classification of submarines. Sonar is presently offering the best solution to this problem. However, shortcomings in equipment performance have frequently resulted from transducers being mounted on ships and inside of domes, particularly when the beam is electronically steered downward. The Navy needs to understand the causes of such shortcomings and to develop the ability to design transducers with assurance of meeting performance specifications. The work of this branch is largely aimed toward giving the Navy this capability.

Technical Program

S01-28 Basic Radiation Theory

This problem is devoted to preparation of reports, constituting chapters of a book, and computation and publications of tables of functions pertaining to transducer radiation and interaction

problems. Only the branch head is available part time for this work. His efforts should be supplemented by those of a theoretical physicist and a mathematician. It is recommended specifically that recruitment provide a replacement for Mr. Blizzard, and that Mr. Blizzard be assigned to this problem.

S01-29 Mathematicial Models

This problem and the next are closely related. The effort here is specifically on a three mass design of element and on interaction effects which will increase the effects of environment on ships. In addition, a theory of feedback control for stabilizing elements in arrays will be carried out. The committee is impressed by the filter-theory approach for the three mass system and suggests that filter-theory may be employed to further advantage by introducing impedance matching half sections.

S02-12 Electroacoustic Modeling

This problem as a counterpart to S01-29 will verify theory and/or determine deviation from theory by utilizing scale models of transducer elements arranged in arrays. These will be tested in the new tank in Building A59 which is adequate to handle the smaller arrays involved in scale models at frequencies in the 15-30 Khz range. This problem also is concerned with developing technique for near-field measurements of transducers being calibrated. Many ramifications of current techniques will be studied, with emphasis, however, on establishing the effectiveness of the present array. A problem exists in funding facilities at Seneca Lake which are essential to the test and calibration of the large near-field array. Current problems are in connection with the Lighter which needs to have its final outfitting carried out before it can be used as an interim vehicle for near-field measurements. Funding appropriated from the Division budget for this problem has exhausted the Division reserve. Furthermore, development of the near-field barge is inadequately funded and the Division has recommended that the Underwater Sound Laboratory be made a partner in this particular vehicle in order that funding shall become adequate. This work should lead to in situ calibration techniques. This particular problem appears to fall in the area of responsibility of USRD. It is therefore recommended that NAVSHIPS, Sound Division, and USRD, get together and discuss this problem in more detail and arrive at a cooperative effort.

K03-07 Technical Service

This problem includes operation of all the Sound Division pressure facilities and includes the provision of a staging tank. The committee inquired into the need for the increased size of this staging tank. The increased size is not an absolute requirement but users generally agree that an effort should be made to obtain as large a tank as can be afforded. An acoustic lining for the largest present pressure tank would render it suitable for acoustic tests at 30 kHz. This is a desirable utilization. A larger tank, if acquired by the Sound Division, would find little use within the Division unless equipped with anechoic linings. The Division sees an interim need for access to a tank of some such size as 10 ft. in diameter and 20 ft. long and considers that provision of such a tank at USRD would provide the services needed by the Sound Division. The committee agrees.

Reporting

Table I is a list of the reports of the Transducer Branch for this review period. The committee feels that the branch has done well in reporting.

Future Plans

The long range plans of the branch include attacking the feedback problem for stability and added control, the provision of a super power source involving explosives in conjunction with an array of apertures and a relative new idea for producing a low frequency directive beam by utilizing high frequencies in conjunction with the non-linearity of the medium. In situ calibration techniques appear to be in the offering and the tie in with USRD remains to be established.

The committee recognizes, and stresses, that experimentation with transducers has become costly as a result of going to low frequencies. The committee therefore, lauds the utilization by the branch of scale model techniques which will somewhat alleviate the problem. However, it is recognized that there remains many problems at full scale which can only be carried out with large elements and arrays, and with elaborate test facilities. Therefore the funding has been no more than adequate and it now appears desirable to increase the funding for the near-field barge at Seneca Lake by taking USNUSL as a partner in this particular barge.

Table I - Summary of Technical

Reporting by Transducer Branch for Calendar Year 1966

(1) NRL Report 6472, "Tables of Spheroidal Wave Functions, Part I - Oblate Radial Functions of the First and Second Type, by S. Hanish, Carolyn Shely, and R. V. Baier, 398 pp. and figs., December 23, 1966.

The theory of oblate spheroidal wave functions is briefly reviewed and a list of literature references to applications of oblate spheroidal theory if furnished. Formulas useful for the numerical calculation of oblate radial functions of the first and second type, together with their first derivatives, are derived and explained. A step-by-step procedure of computation is then outlined together with an indication of precision obtained and method of checking. Finally a computer-printout tabulation of 72,300 entries comprising radial functions and and their derivatives is reproduced. The range of parameters m = 0 (1) 4, l = m (1) 8, g = 0.1(0.1) 1 (0.2) 8, and = 0.1 (0.1) 0.9. To these are added several special sections. A special section = 0 covers all the above ranges of g and l for m = 0(1) 8. Another section = 0 covers the above range of g for m = 0,1 and = 9 (1) 18.

(2) NRL Report 6502, "Tables of Spheroidal Wave Functions, Part 2 - Prolate Radial Functions of the First and Second Type, by S. Hanish, R. V. Baier, W. H. Buckler, and Berthel K. Carmichael, 390 pp., January 31, 1967.

The theory of prolate spheroidal wave functions is briefly reviewed. Formulas useful for the numerical calculation of prolate radial function of the first and second type, together with their first derivatives, are derived and explained. A step-by-step procedure of computation is then outlined together with an indication of precision achieved and method of checking. Finally a computer-printout tabulation of 66,600 entries comprising prolate radial functions and their first derivatives of both types is reproduced. The range of parameters m, l, h, and covered in these tables is m = 0 and 1, l = m (1) 18, h = 0.1(0.1) 1 (0.2) 8, and = 1.01 (0.01) 1.10.

(3) NRL Memorandum Report 1688, "A Review of World Contributions from 1945 to 1965 to the Theory of Acoustic Radiation, Chapter III - Theory of Transient Radiation", by S. Hanish, 100 pages, 10 March 1966.

Contents: Review of latest developments in the field of transient acoustic radiation. Includes discussion of recent work of Kozina, Miles, Brillouin, Lauvstad, Schoch, Polk, Pachner, Barakat.

(4) "Near-Field Calibration Array", by George Pida. Talk given at the 24th U. S. Navy Symposium on Underwater Acoustics at Phila., Pa., Dec. 1966. To be published in the Proceedings of the 24th U. S. Navy Symposium on Underwater Acoustics - August 1967. 10 pages.

Contents: This report presents details on (1) a review of the theory and progress to date of the Near-Field Program, (2) the design of the 40 ft x 40 ft structural frame required to support the 50-column hydrophones, (3) underwater acoustic measurements on completed columns, and (4) initial data on the acoustic performance of the assembled array.

(5) "Determination of the Far-Field Transducer Characteristics by Near-Field Analysis", presentation by R. V. Baier, Sponsor's Day Program, NRL, April 1966, 12 pages.

Contents: Introduces the theory of near-field testing and difficulties. Present in the analytic work. Design criterion for the near-field calibration array is defined and numerical results are presented for a 17 ft cube plane wave core. Some experimental results for a single line of 50 shaded sources are compared to theoretical calculations.

Electronics Branch

The two problems on Signal Processing Research and Data Presentation are lumped together in what follows.

1. Objectives

The primary objective of the work is to determine the distortion acquired by signals propagated over paths in the ocean up to hundreds of miles in length. Both temporal and spatial coherence are measured, with separations of hundreds of miles between data collection positions for spatial coherence. In the processing of data, various types of analysis are performed automatically by a computer. It therefore contributes to the problem to find short cuts in computations by means of special programs. Of special interest are the ambiguity functions of various signal which may be used. Properties of ambiguity functions are studied and ambiguity functions are computed of various pseudo-random noise (PN) sequences for research use.

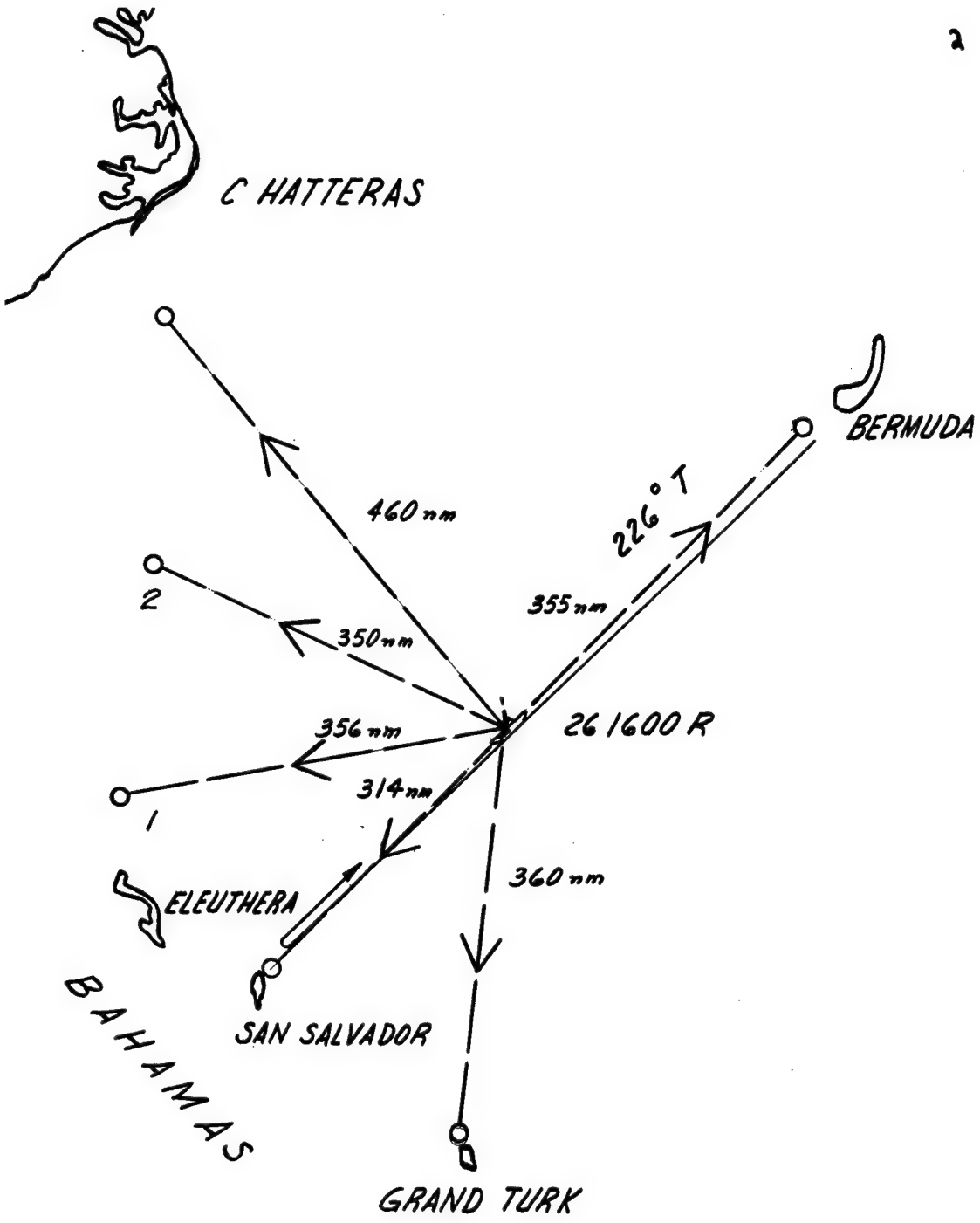
2. Productivity

During the past year, a fast Fourier transform has been introduced into the computer program decreasing the number of operations in the computer from N^2 to $2N \log_2 N$, where N is the number of sample points involved. When dealing with thousands of sample points this represents a considerable saving in computer time.

A field trip in November 1966 provided recording of signals transmitted from a transducer towed by the USS WITEK and received at several stations approximately as indicated in Fig. 7. The type of on-line operational processing made at various stations is a plot of frequency versus time as shown in Fig. 8. For the purpose of the experimental work here, the important portion is the broad-band signal burst recurring periodically. Receptions at different points were correlated against each other. Typical results are shown in Fig. 9. The repetitive peaks result from the use of a PN signal with a periodicity of 1.28 seconds.

3. Future Plans

Development of techniques using hybrid computer elements will be carried out to find methods of building fixed wired systems for fast operations, for on-line



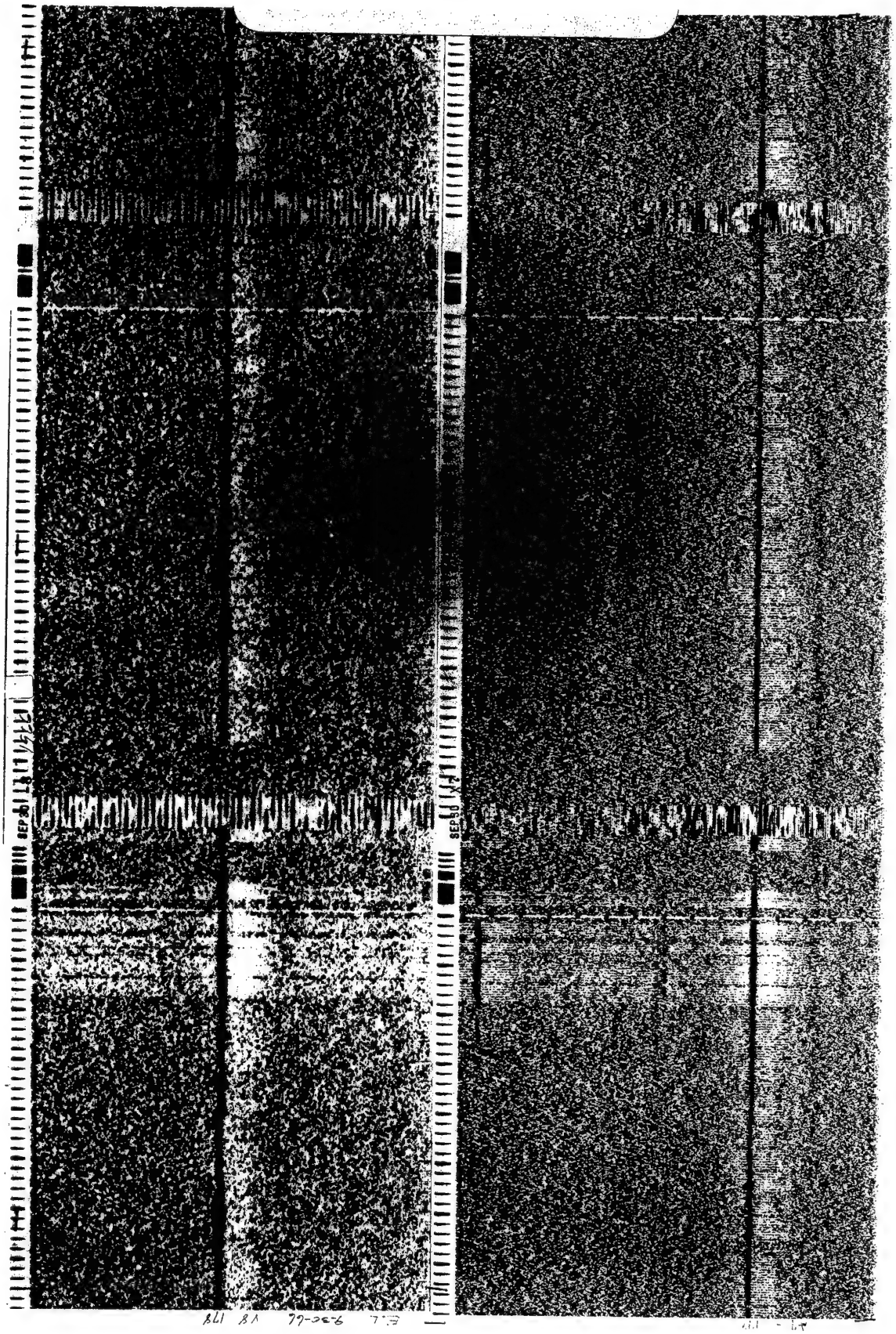
LONG BASELINE EXPERIMENT 9-66

GROUP 4 CONFIDENTIAL

Fig. 7 -- STATION LOCATION

Fig. 8

SIGNAL RECORD



CROSS CORRELATION OF DATA PAIRS

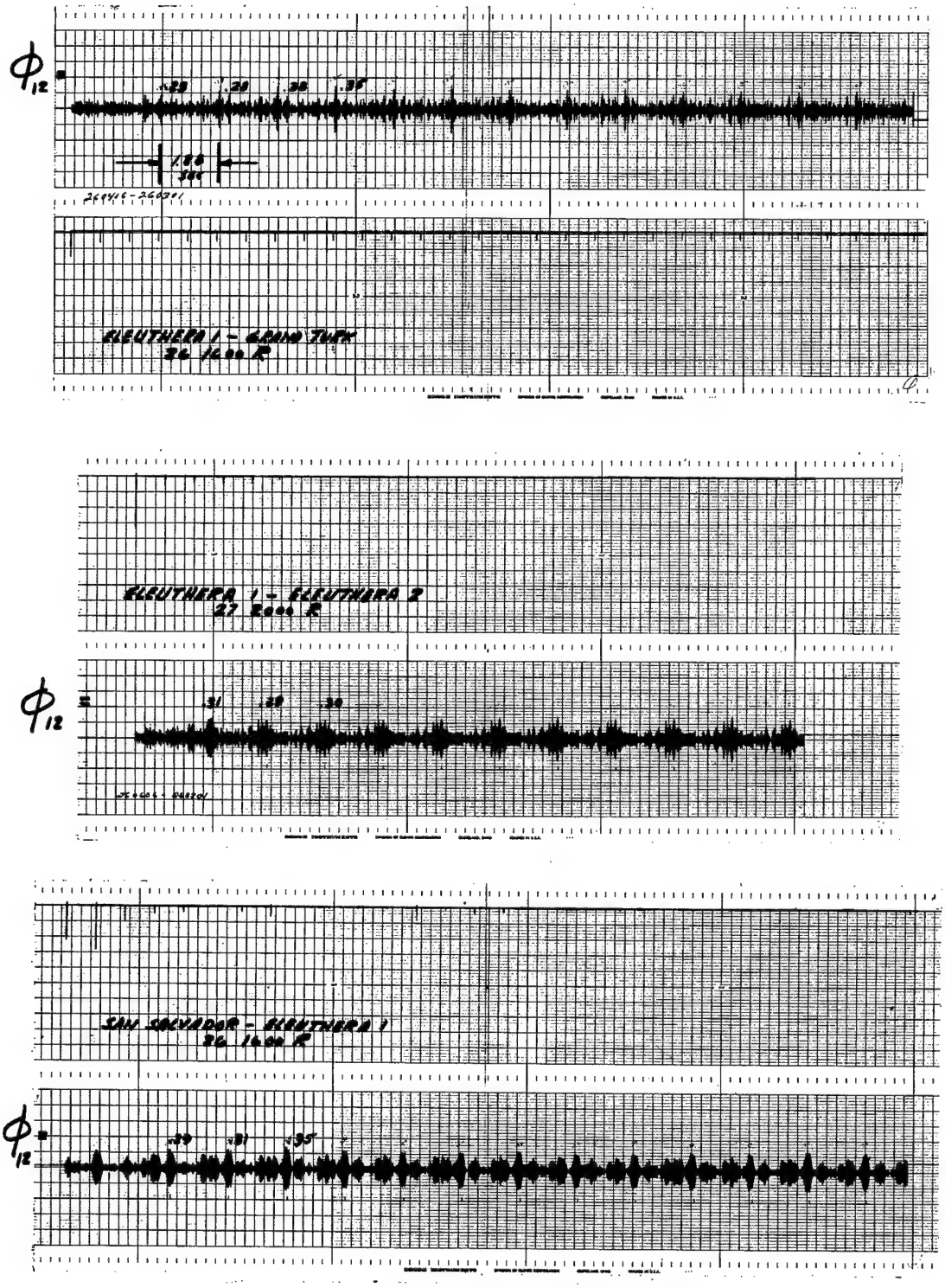


Fig. 9

GROUP III

SPATIAL COHERENCE
OF PN SIGNALS

operation in surveillance systems. Power spectrum study will be continued. Propagation effects on amplitude correlation and spectrum for continually increasing range using best PN source will be studied. Relative or absolute calibration of receiving arrays will be established, cooperating with BTL and others. Ambiguity functions for various signals having short and long base lines will be constructed. Signal deterioration will be determined after long-range propagation with various oceanographic conditions. Methods for interharmonic analysis for separation of signals from different sources will be implemented.

Ship maneuvers are planned in exercises during August 1967 which will enable obtaining doppler shifts varying in different manners at different pick-up stations during a number of planned circlings of the transmitting vessel. In addition, variation in geographic locations will result in varying angles and should uncover effects of bottom topography over different paths.

REPORT OF REVIEW COMMITTEE ON PROGRESS OF ELECTRONICS BRANCH, SOUND DIVISION

The review committee for the Electronics Branch was composed of:

Dr. H. L. Saxton, Chairman
Dr. R. L. Steinberger
Mr. H. L. Peterson
Dr. J. J. Freeman

Nature of Program

This program is research, using ONR General 6.2 funding. Instrumentation for this research is refined and effective with one limitation to be discussed later. The program involves facets which may directly affect fleet equipment design for passive surveillance systems. It may also lead to signal design for active search and classification systems. Consultative services have been furnished to upper echelons on techniques and equipment for acquiring intelligence information.

Navy Need

The Navy needs the capability for larger submarine detection range and improved classification means. It needs a capability for passive ranging. It also needs to know characteristics of every submarine to guide the choice of detection equipment. Information obtained in this program is directly applicable to these needs.

Cohesiveness

The program is exceptionally cohesive. Research is on signal characteristics, signal distortions, signal design, and techniques for design and analysis. Laboratory work is both theoretical and experimental. Field trips on an extensive scale have provided data. Individuals have been made responsible for different aspects of the program with continuous coordination of their work and cross fertilization.

Theoretical Research

The group is delving into fundamental theories of communication theory. It has contributed to this theory and has also applied general theory to specific cases. Certain important theoretical aspects are still unknown, for example, how to design a time sequence to have a desired ambiguity function,

and how most advantageously to process three or more coherent signals. Help on problems of this sort which crop up frequently is expected from Dr. Lee of George Washington University, who is being processed as a part time consultant. Communication with others in this and related fields should be improved. A mechanism is discussed later.

Instrumentation

Experimental research is abetted by refined instrumentation for recording and handling data. It provides generation of pseudo-random noise (PN) of desired frequency, bandwidth and pulse length, conversion both from analog to digital form and vice versa, computation of auto. and cross correlation functions and spectrum analysis. Various techniques for speeding up computations have been devised. The computer is modern and fast for a small computer. It is adapted to branch needs, and is provided with desirable peripheral equipment, some of which is lacking with the centrol laboratory computer. Additional computer memory of 4,000 words should be obtained to double the capacity and permit tripling of the sample sequence which can be correlated in one piece.

Experimental Research

Research is aimed at the following projects:

(a) Correlation and power spectrum of PN. The committee notes an absence of any attempt to complicate the coding in order to defy decoding except by those knowledgable of the coding system. The project may very well lead into this process for secure communication. The committ ee approves the fact that auto-correlation functions of PN by phase reversals will be determined and compared with the types produced by the branch. Comparison of a frequency-slide signal should also be made.

(b) Effect of simulated doppler on digitally computed cross correlation. This is an approach to ultimate two-dimensional correlation functions which are required in processing dopplered signals. The problem of real time processing

[redacted]

should continue to receive attention.

(c) Artemis Experiments. The huge Artemis source and selected modules have been used to carry out one-way transmission studies and to determine coherence of signals at various pairs of modules. Further data involving doppler shifts will be taken and analyzed as one approach to two-dimensional correlation functions. This endeavor should be kept secondary to the long baseline field work.

(d) Long Baseline Experiments. Cross correlation between signals received at points hundreds of miles apart have been carried out. Future plans are for exercises involving the generation of various doppler shifts by source ship maneuvering. Various frequencies, bandwidths and PN types would also contribute to an understanding of the problem. The question of absolute calibration was discussed in the committee. Such calibration cannot be obtained unless gain control settings under the control of fleet operators are held fixed. If this can be arranged, there remains the problem of different sensitivities in different receiving beams. No immediate solution is seen. Controlled doppler shifts will be introduced.

(e) Phase Fluctations. The work carried out by the group together with that of Steinberg at University of Miami, display unexpected stability with such variations as exist related primarily to tides. Experiments on a grand scale from Eleuthera to Bermuda are hoped for.

Technical Contacts

The review committee discussed the trade-off aspects of time spent in contacts and time spent in research. It is difficult to assess the value of contacts in advance. The idea of scientific liaison provided by staff members is appealing. Consultants now perform this function in a limited amount. They may point out particular contacts which should be valuable and also provide negative information, when merited, to save the time of other scientists.

[redacted]

Funding

Funding has generally been adequate. An additional sum of 18K for FY 68 used to procure a memory bank of 4,000 words would pay off hansomely in time saved.

Personnel

Personnel are well coordinated and individually effective. The addition of Dr. Lee, part time, will add strength on the theoretical side. Other part time consultants who could appreciably strengthen the program are: Dr. Tufts of Harvard University and Manny Young, the latter an expert on on-line data processing with hybrid computer methods.

Reports

Table 1 lists reports published by members of the Electronics Branch during the reporting period. The number of reports would be considered adequate except for the fact that several of them are very short. More extensive reporting, particularly on results of field trips, is expected for the next year.

Future Plans

ARTEMIS data- Correlation processing of ARTEMIS data.

Continue processing one-way propagation data backlog from previous field trips.

a. Compare received signal with the transmitted signal by correlation to find amount of degradation with range, various sea conditions and other parameters.

b. Cross-correlate between modules for short baseline correlation values.

c. Study time stability of received data.

Power spectrum analysis techniques.

Develop faster and more accurate methods through the use of general purpose and special purpose computers.

[redacted]

a. Develop use of Fast Fourier Transform for either fixed or software systems.

b. Study statistical accuracy and stability of data.

c. Use digital, hybrid and analog computers to develop the best applicable methods for field and lab use.

d. Orient work toward on-line operation, e.g., use in surveillance systems.

e. Inter-harmonic study: Study and implement methods to identify and/or display harmonics of the same signature.

Signal Design and Ambiguity Study

Provide optimum signals for future field experiments. Include variation of frequency and band width.

Specific tasks:

a. Continue present lab experiments to find a PN sequence that exhibits good correlation peak-to-side-noise ratios for various dopplers.

b. Theoretical studies and practical applications of methods of signal synthesis using, e.g., Huggins and perhaps Walsh functions.

c. Field experiments to find fundamental data on amplitude and phase fluctuations, caused by the medium and for various oceanographic factors. Isolate, if possible, to find the effect only of surface reflections, bottom reflection, volume reverberation, target reflections, etc.

d. Field experiments to test out use of PN sequences.

e. Use of theory and field data from above experiments to try synthesizing signals that are invariant to distortion and/or signals that match given target characteristics.

f. Build into experiment ways to get doppler and plot the two-dimensional correlation function for signal returns as a means of judging the usefulness of a given signal for a given propagation situation.

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Long Baseline Experiments with particular exphasis for SOSUS

Run field experiments to establish the two-dimensional correlation function and compute the spectrum for both short and long baseline data.

a. For various oceanographic conditions and for various signal types, and for increasing range for ARTEMIS systems and adjacent SOSUS area.

b. Establish relative and/or absolute calibration and levels for stations.

c. Cooperate with BTL, STIC-III, etc., to incorporate as many experiments as possible.

d. Study time stability of paths.

Wavefront Stability with specific application to ARTEMIS

Measure the amount of fluctuation in amplitude and arrival time of pulsed signals for one-way propagation to the ARTEMIS receivers.

a. Measure the wavefront stability electronically on the ARTEMIS receiving modules using multiversity pulse phase fluctuation measuring system similar to cumulative phase difference systems.

b. Show relationship of wavefront to signal degradation when combining into a linear planar array.

c. Simulate also in lab by resampling with time$_{lags}$ to represent wavefront distortion and sum over a number of N say of delayed signals to get composite sum. Simulate continuous wavefront warp or with random warp.

d. Continue cumulative phase measurements.

Recommendations

The committee recommends that:

1. Experimental work be extended in scope with more variability of parameters, for example, frequency and bandwidth.

2. The problems of classification and communication be held in mind in order to branch out in an effort to study or meet these problems whenever

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interesting possibilities are uncovered.

3. Pin down the relative advantages of PN noises produced by the phase reversal and filter methods.

4. Seek a solution to the problem of absolute calibration of receiving arrays already in the ocean.

5. Establish and improve liasion with other Laboratories.

6. Procure a memory bank of 4,000 words to augment the present 4,000 word capacity of the branch's computer.

7. Set up part time jobs for the consultants under present consideration and attempt to enlist their services.

[redacted]

Title	No. Pages	No. Tables	No. Figures	Comments
H. L. Peterson, Caldwell McCoy, Jr. and G. G. Nacht; "Cumulative Phase Fluctuation Measurements in Signals in Underwater Acoustics," Report of NRL Progress, Problem Notes, February 1966, pp 30-32.	2	0	2	Shows examples of sine wave underwater acoustic transmission and the randomness of the cumulative phase of the received signals as measured by a hybrid cumulative phase difference meter.
H. L. Peterson and G. G. Nacht; "A Hybrid Cumulative Phase Difference Meter," Report of NRL Progress, Supporting Techniques, February 1966, pp 37-38.	2	0	3	Short description of a meter that is being used to measure and indicate on a graphical chart or CRO the instantaneous crossing phase of received underwater signals relative to the original.
D. A. Swick; "Customizing Acoustic Signals," Report of NRL Progress, Research Highlights Issue, Electronics Area, December 1966, pp 13-14.	1	0	0	Short description of mathematical derivation of ambiguity function previously described in NRL Report 6471 below.
D. C. Coulter and G. V. Olds; "Fast Fourier Transform," Report of NRL Progress, Research Highlights Issue, Electronics Area, December 1966, pp 14-15.	1	0	0	Reporting of work on programming the "Fast Fourier Transform" and some comparisons of running time on some computers at NRL.
D. A. Swick; "An Ambiguity Function Independent of Assumptions about Bandwidth and Carrier Frequency," Report of NRL Progress, Problem Notes, October 1966, p 33.	1	0	0	Summary of NRL Report 6471 below.
D. A. Swick; "An Ambiguity Function Independent of Assumptions About Bandwidth and Carrier Frequency," NRL Report 6471.	7	0	0	A Generalized ambiguity function is developed which is independent of assumptions about bandwidth and carrier. Comparison is made with the Woodward ambiguity function which has narrow band assumptions.
D. A. Swick; "Discrete Finite Fourier Transforms, A Tutorial Approach," NRL Report 6557 (In reproduction).	24	0	0	Discrete finite Fourier Transforms are derived from basic principles. An appendix describes the efficient use of FFT Algorithms.
Caldwell McCoy, Jr. and H. L. Peterson; "A System for Measuring the First and Second Order Probability Distributions of Signals and Noise," NRL Report 6522 (In reproduction).	32	0	22	This report describes a system to do real time processing on analog signals by converting them to digital form and obtaining the first or second order frequency of occurrences. From these numbers the corresponding amplitude probability density distributions are computed.

TABLE I

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Techniques Branch

1. Objectives

a) Environmental Reverberation Studies -- Objectives are to relate microbubble content of the acoustic environment to differential sound speed and sound absorption, to measure in the laboratory acoustic scattering and absorption in aqueous mixtures of known particulate contents, to examine the characteristics of particulates in natural waters using electron microscopy, the Coulter counter and other appropriate techniques, and to test the hypothesis that a stable bubble population exists in natural water systems.

b) Assured Range Studies -- The objectives are to determine mechanisms by which energy in an ocean surface duct leaks out into the shadow zone, to determine losses from a source in the layer to a receiver below the layer in the shadow zone, and over the return path, to measure echo-to-reverberation ratios using a synthetic target, and to examine the possibility of exploiting the leakage path in operating systems including the development of effective signal processing.

c) Acoustic Countermeasure Techniques Investigation -- Objectives are to determine the value of low power space diversity decoys against the new MK 46 torpedo, to determine the kind and amount of realism required in a decoy to deceive modern sonars and their operators, to determine the value of DAPHNE techniques to control the logic of modern torpedoes such as the MK 46, and to determine the value of using DAPHNE techniques and high frequency harmonics produced by sonars to countermeasure torpedoes.

Known acoustic and torpedo countermeasures are analyzed, and major improvements are recommended. New, more efficient acoustic countermeasures techniques are originated and their capability is determined and demonstrated. "Logic" for use by known and new acoustic countermeasures is developed and Quick Reaction Capability to make immediate use of intelligence data or available foreign equipment is maintained.

2. Productivity

a) Environmental Reverberation Studies -- The Vitro microbubble analyzer is essentially completed. Some technical difficulties were encountered which have

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resulted in an over-run. Work is continuing pending funding arrangements.

The data reduction and analysis of the 16 February - 5 March 1966 Key West Field operation is nearly completed and a formal laboratory report is partially complete. The report is quite comprehensive and shows the correlation of acoustic scattering data with the particulate distribution and other independent measurements. Electron microscopy has also shown that the particles found in certain scattering layers are of the same material as those previously observed in the area. One of the best examples to illustrate the approach is from an earlier trip where electron microscopy revealed completely different structure in and out of a scattering layer, see Fig. 10.

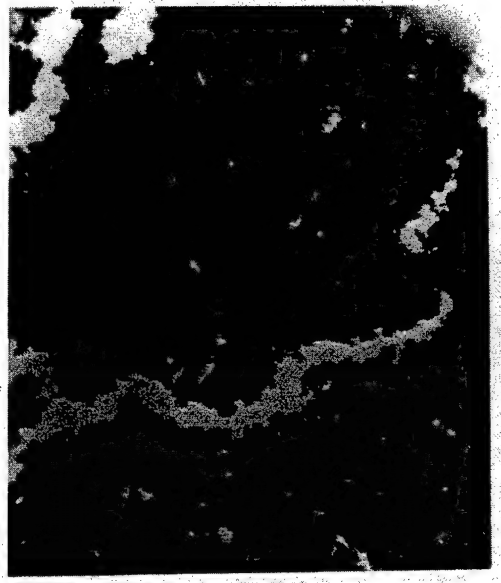
Invironmental acoustic studies conducted at the U.S. Navy 3-D Torpedo Range, Dabob Bay, during October 1966 revealed the presence of a scattering layer at 200 ft. which had excess attenuation and reverberation properties.

Due to cancellation of the San Juan, Puerto Rico, field operations an alternate operation in the Yucatan Straits was conducted between 8 and 15 February 1967 using the USNS MIZAR. These tests were in cooperation with NRL problem 55S01-31. The trip included the Naval Ordnance Test Station, Naval Ship Systems Command and KWESTEVDET as participants. Comprehensive data were obtained using acoustic profilers, sound velocimeters, optical instrumentation, the Coulter particle counter, bathymetric instruments and water sample collection for electron microscopy studies.

A new concept in particle counting has been laboratory demonstrated and checked against Coulter counter particle counts on water samples obtained in the Yucatan Straits during February 1967. The new counter operates electroacoustically by scanning the particles transferred to a gelatin-base plate from a membrane filter. The scanning unit is a low pressure stylus phonograph pickup and the readout is by digital counter. The principles of operation and early test data are given in Reference (2).

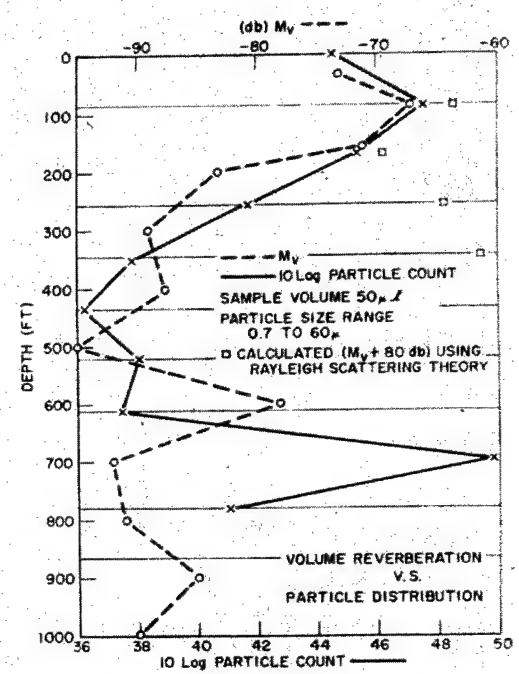
A small acoustic tank has been instrumented for measuring the scattering and absorption from particles suspended in liquid media. The particles are contained in plastic containers which are immersed in the tank between the sending and receiving transducers. Calibration of the system is progressing and methods for generating bubble screens with controlled bubble size are being investigated.

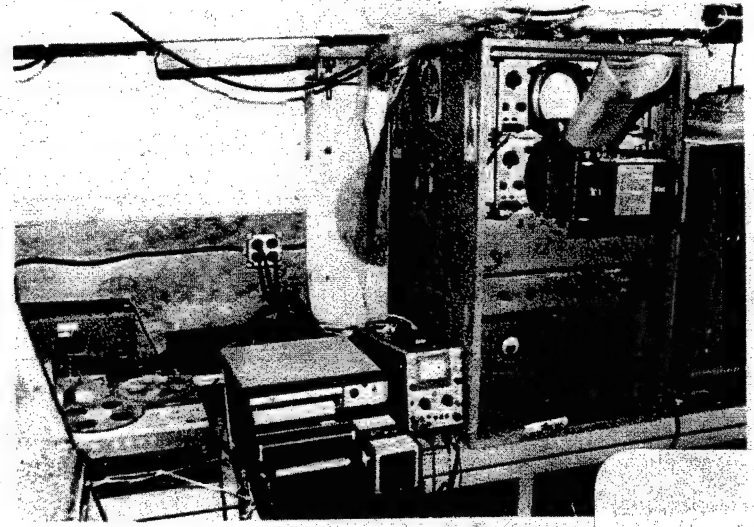
REVERBERATIONS AND PARTICULATES



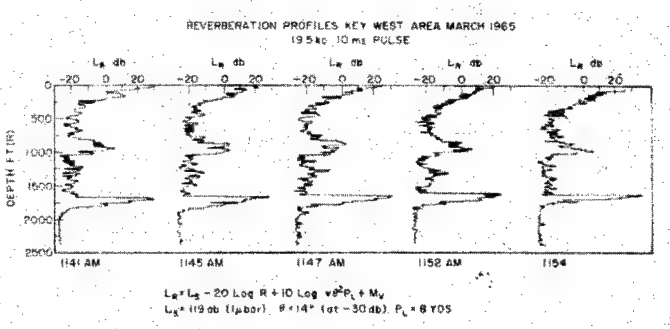
Particulates 650ft.

Particulates 20ft.





ACOUSTIC PROFILER



PROFILES

Fig. 10

STRUCTURE OF WATER IN AND OUT OF SCATTERING LAYERS

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b) Assured Range Studies -- A check of normal mode theory against experimental results indicated that the acoustic level in the shadow zone is much higher than predicted by normal mode theory. The excess level must be attributed to scattering, whether from the surface or from bubbles or particles near the surface. During the past year, the Sound Division has made moderate progress in the ray-theory approach to scattering from the surface. The theory of caustics has been developed. The literature on scattering from the surface has been reviewed, and work has progressed on the formulation of a mathematical model to explain leakage from the duct and to provide prediction of sound levels in the shadow zone.

A field trip to the region east of the Yucatan Peninsula and southwest of the western tip of Cuba was mounted in February 1967. The data taken on this problem include the measurement of propagation loss from a source on a surface ship to points in the shadow zone, the loss on the return path, and echo to reverberation ratios. A partial analysis has been carried out. In Fig. 11, the sound-speed profile indicates a layer depth of 200 feet. The figure shows the vertical profile of propagation loss predicted by normal mode theory for one way propagation and, for comparison, the profiles of the measured propagation loss each way. It will be noted that below 300 ft. depth the measured loss is substantially less than predicted by normal mode theory. It is worthy of note that the loss on the return trip from below the duct, which has seldom been measured in the past, is substantially less than on the outgoing trip. This typical result, obtained at sea state three, is regarded as encouraging to the undertaking of detection in the shadow zone.

c) Acoustic Countermeasure Techniques Investigation -- The secret nature of progress in this area precludes inclusion in the report. However, it may be related that five separate investigations have each contributed to advances in knowledge or techniques related to countermeasures.

3. Future Plans

a) Environmental Reverberation Studies -- Increased sophistication in instrumentation and more critical examination of acoustic scattering theory is the goal for continued research. Contributions to several other problems will be offered. Scattering profiles will be useful in the computations of assured range into shadow

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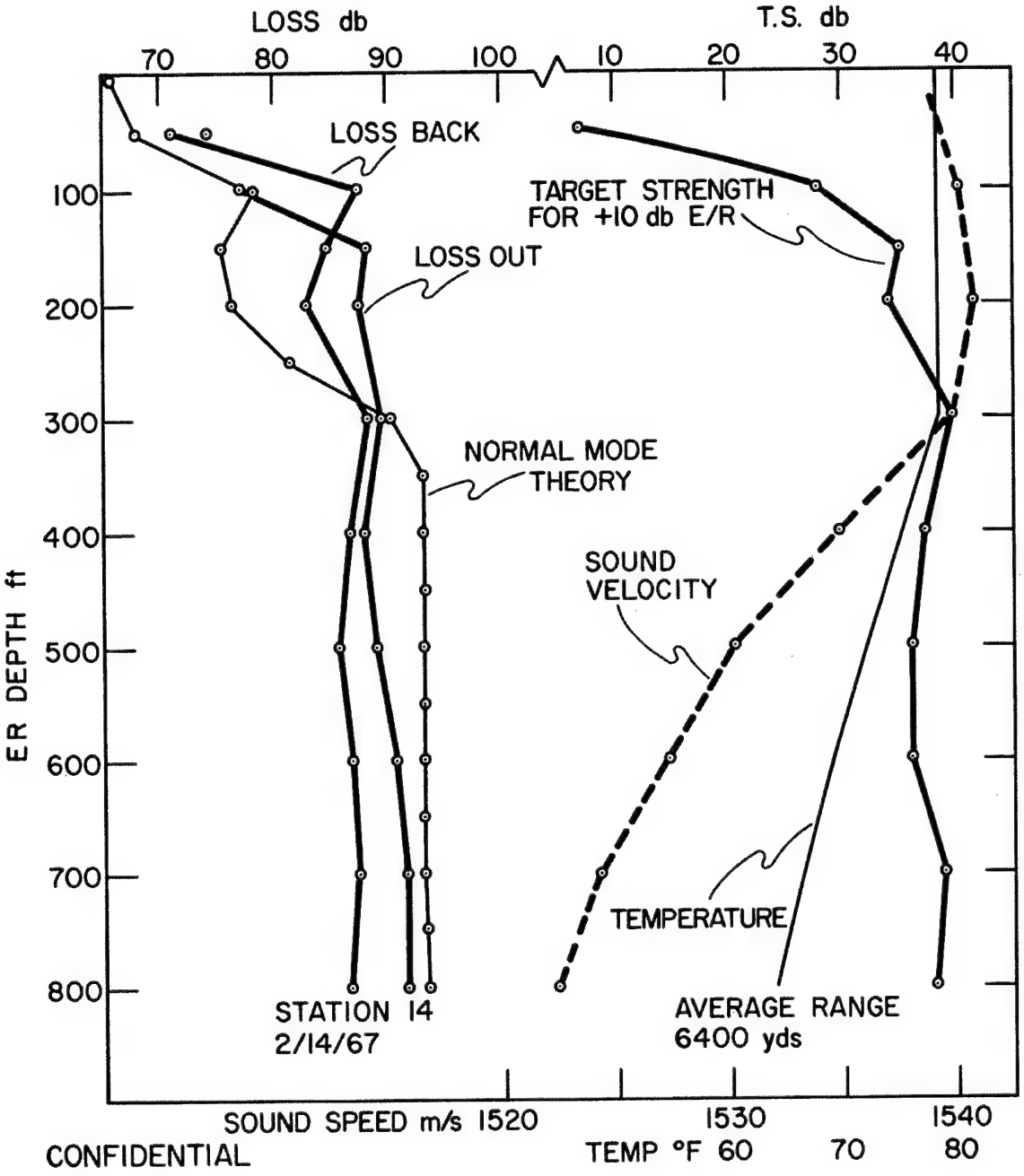

Fig. 11 -- TEMPERATURE AND LOSS PROFILES

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zones, and also in the prediction of desirable restriction on torpedo depths. Acoustic methods may supplant the use of Nansen Casts and other water sampling methods for some purposes where a rapid indication of particulate distribution is required.

b) Assured Range Studies -- Experiments are planned to gain more knowledge on this problem and to determine gains obtainable by combining optimum paths with effective techniques to improve signal-to-background ratio. Examples of techniques are: narrow-beam source and receiver, use of short pulses, noise and reverberation rejection circuits in which the coherent parts of noise and reverberation are balanced out. If results warrant, an experimental sonar system to extend the range in the near shadow zone will be designed, developed, and procured. Tests will be conducted to determine the effectiveness of this sonar when it becomes available. Theory suitable for performance prediction will be formulated.

c) Acoustic Countermeasure Techniques Investigation -- Experiments and analysis will be carried out on a new-concept decoy to show tactical usefulness against modern torpedoes such as the MK 46. Hardware possibilities of the realistic decoy concept will be examined and experiments will be designed to verify conclusions. A Quick Reaction Capability will be maintained to capitalize on new information or hardware related to acoustic countermeasures that become available from intelligence sources.

An ongoing program of evolving and evaluating countermeasures techniques will be instigated using a new simulation facility. This will be backed up by field tests to check techniques and situations which can not be accurately simulated.

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REPORT OF REVIEW COMMITTEE FOR THE TECHNIQUES BRANCH, SOUND DIVISION

Committee

The review committee for the 1966 - 67 period is comprised of:

H. L. Saxton, Chairman
W. R. Faust
S. Hanish
R. H. Mathes

The committee met on March 29, 1967, the day following the presentation and discussed the program at some length.

Nature of Work

The work of the Techniques Branch tends to run the gamut from basic research to systems. Presently, three of the four problems are in the research phase. The fourth problem has a natural spread by assignment of NAVSHIPS and includes research, development, systems analysis, evaluation and modification for improvement. As with other branches of the Sound Division, 6.2 funding predominates. This seems appropriate in large part because of the applied nature of some of the research.

Navy Needs

The need for torpedo countermeasures is well established. Applications of "Acoustic Countermeasure Techniques Investigation" were presented by the branch.

In its ASW effort, the Navy needs the capability of establishing and maintaining observational contact with enemy submarines in shadow zones. "Assured range studies" is assessing the potential in this direction by the use of leakage energy from a surface-bounded sound duct.

The Navy needs correlation of acoustic scattering and particulate distribution as a means of predicting the one from the other. Resulting from "Environmental Reverberation Studies" could be prediction of sound scattering profiles by optical means on aircraft, and/or prediction of effectiveness of visual operation from aircraft from sound scatterer profiles.

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The need exists for increased area coverage rate in submarine detection from aircraft. Visual observation (i.e., optical at visual frequencies) for satisfying this need are being studied in "Underseas Warfare Research".

Cohesiveness of the Program

The specific phenomenon which ties the four tasks of the Techniques Branch together is acoustic reverberation in relationship to scatterers. Reverberation per se is of utmost importance in "Assured Range Studies" both as a limitation on detection and as an indicator of the existence of scatterers as leakage agents. Scattering profiles also may establish particulate distributions and potential redistributions. Scattering layers may affect torpedo operation and countermeasures as a function of torpedo depth.

Acoustic Countermeasure Techniques Investigation (S)

This is a 2 man year effort with generous funding which could support 4 man years. The list of devices developed, tested, and modified is evidence of substantial contribution.

The Branch has been unable to recruit qualified manpower. The alternative of training people seems necessary.

Future plans call for proceeding along the same lines as at present, developing new devices as ideas are conceived, and improving older devices.

Assured Range Studies

This problem has proceeded on schedule through theoretical and experimental phases. The complex normal mode theory in its present form is well in hand but in

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fact is descriptive of only an ideal situation. Its extension to more complicated duct-boundary conditions is desirable. The present form of the theory has been shown in one field trip to be inadequate. The criterion for establishing location in or out of the shadow zone is being applied by accurate methods for all stations. This study is highly important.

Scattering theory is being attacked from the ray-theory approach with surface scattering related to frequency of incidences and to wave height. A tie-in with normal mode theory may be found through the relationship of limit rays to angles of surface incidence associated with eigen values of trapped modes of highest mode number. Leakage is expected to be enhanced by scattering, and enhancement by some mechanism will become obvious from experimental data provided these data are established as applying to the shadow zone. A simple calculation can determine this.

Another scattering mechanism—that of bubbles or particulates—can be attacked by the nuclear transport approach. Manpower is inadequate for attacking application of this theory now before other approaches are further advanced.

Funding is marginal. Any supplemental contribution of ONR general funds can be used to advantage during the research period during which results may convince NAVSHIPS of the great promise of the problem and may influence them to increase their support.

Environmental Reverberation Studies

This Laboratory is practically alone in recognizing a relationship of scattering strength to particulate distribution. The inability of particulates to account for observed high scattering profiles even though its profiles are similar in shape has led to the hypothesis of bubbles formed on particulates. Theories of stable bubbles have been advanced. Instrumentation is being developed to measure both particle and bubble density in situ in the ocean. Agreement between scatter theory and observed scatter as a function of observed bubble content would be a marked step forward. Alternatively, proof of the existence of gels or bacteria accounting for scatter would be valuable.

[redacted]

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The funding of this problem is subject to the whims of the sponsor who speaks of 200K one moment and 50K the next. 50K is woefully inadequate. ONR funding is especially needed on this basic problem. Experiments at sea have to a considerable extent ridden on the coattails of other branch problems. The correlation with other problems should continue even with adequate funding.

Underseas Warfare Research

This is the non-acoustic counterpart of the previous problem with emphasis on the redistribution of particulates after passage of a submarine, and the resulting optical effects from above in the visible spectrum. Results are encouraging and are beginning to receive favorable recognition outside the laboratory as evidenced by references to work here.

The Sound Division attitude toward technical control by a Project Officer is unfavorable because it appears not to really exist. Technical control includes involvement in, and thorough understanding of, experiment planning and data analysis as well as review and reporting. Criticism should not be addressed to outsiders without detailed discussions within the Branch. Such involvement is disavowed by the Branch.

Termination of the problem, since it is not acoustic, is a wish of the Sound Division, but only under the following conditions: a) problem transfer should be established in order that this important work may be continued by others; b) funding should be increased on the acoustic phases of the work under the previously reported problem, and personnel transferred; c) some of the personnel should be transferred to the acoustic phases of particulates and 1 or 2 to countermeasures work where funding is already adequate.

Personnel Summary

In summary, personnel are badly needed and hard to find for countermeasures work, and more theoretical manpower is desirable on all problems.

[redacted]

[redacted]

Funding Summary

Assured Range - marginal. (55 S01-31)

Environmental Reverberation Studies - badly in need of dependable support. (55 S01-26)

Future Plans

Countermeasures will change as new ideas are evolved and as deficiencies in existing equipment are uncovered.

"Assured Range Studies" is expected to go into an equipment phase for demonstrating feasibility after the next field trip provided results warrant it.

"Environmental Reverberation Studies" will concentrate on volume reverberation and particularly in pinning down mechanisms. Artificial production of scatterers with countermeasure implications involving screening will be considered.

"Underseas Warfare Research" will seek further understanding of potentialities with respect to observation from the air, and subsequently will show the way for applicable equipment development.

Recommendations

1. Augment personnel for countermeasures work. Train personnel if necessary.

2. Participate in a new break away problem, if only on a limited basis subject to increased manpower.

3. Acquire one theoretical physicist as a permanent employee.

4. Division pin down NAVSHIPS on support for reverberation studies. Laboratory attempt to augment this support by ONR funding, at the expense of some other Sound Division problems if necessary (e.g., S01-01 suggested by Code 5500), in order to assure continuing dependable support.

5. Plan for the future of the non-acoustic work by conversations among all concerned.

[redacted]

Techniques Branch Personnel Activities

1 April 66 - 1 April 67

Activity	Number of Courses, Membership, etc.
Educational	
University Graduate Courses	
Physics	3
Math	1
Bolt Beranek & Newman Underwater Acoustics	3
Bolt Beranek & Newman Oceanography	1
Bunker Ramo 133 Computer Programming Course	4
RCA Digital Techniques	1
Ohio University R & D Management Course	1
Navy Correspondence Course in Oceanography	2
Navy Correspondence Course in Artic Operations	1
Navy Scuba Diving Course	1
NRL Research Reserve Co. Includes Chairmanship of Counterinsurgency Program	2
NRL Thomas Edison Toastmanster Club	4

Professional Societies

Acoustical Society of America	2
Research Society of America	2
Operations Research Society of America	2
Washington Operations Research Council	1
American Physical Society	2
Institute of Electronic & Electrical Engineers	4
American Ordnance Association	1
International Oceanographi Foundation	1
Marine Technology Society	1
American Society of Mechanical Engineers	1

Navy Committees

Underwater Sound Advisory Group	1
DNL Airborne ASW Committee	1
ARTEMIS System Research Committee	1 (Alternate)
Autec Data Processing & Computer Panel	1
CNM Acoustical & Torpedo CM Workshop	2

NRL Committees

NRL Science Education Committee	1
Board of Civil Service Examiners	1
Micro-Electronics Review Board, Devices Committee	1
Sponsors Day Committee 1966	1

Patents

Disclosures and in process	12
Granted	2
Awards	4

NRL Formal Reports

1. NRL Report 6438, "Some Turbidimetric Observations in the East Siberian Sea During July-September 1964".

2. NRL Report 6441, "NRL Echo-Ranging Experiments".

3. NRL Report 6398, "Characterization of Particulate Matter in the Ocean".

NRL Memorandum Reports

1. Memo Report 1681, "Some Oceanographic Observations Related to the Detection of Submarine Wakes During Field Operations in the Block Island Area 19 - 30 July 1965".

2. Memo Report 1695, "Report on the Analysis of the Two Contractors' Design Study of a Transducer-Driver 'for a Single Source' DAPHNE System".

3. Memo Report 1703, "Low Altitude Photographic Observations of Oceanic Light Scattering Particulates in Chesapeake Bay".

4. * Memo Report 1721, "Acoustic Distance Measuring Equipment for Submarine Survey".

Instruction Manuals

1. *Instruction Manual 52, "Acoustic Distance Measuring Equipment for Radiated Noise Measurements".

Publications in Professional Journals

1. "Propagation of a Planktonic Marine Copepod Through Multiple Generations in the Laboratory" - Published in "Science"

2. "An Iron-Containing Nepheloid Layers off Key West, Florida" - Published in "Nature".

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* In addition to the reports a completely redesigned equipment was furnished in July 1966.

Letter Reports

1. NRL Ltr Report 5550-38 Ser 2451 of 14 Mar 1967, "Some Experiments with a Liquid Filled Acoustic Resonator Showing the Existence of Stable Bubbles in Water" - This will be issued as a Formal NRL Report 6567.

2. NRL Ltr Report 5550-29 Ser 0273 of 16 Mar 1967, "The Observations of Diffuse Acoustic Scattering Layers in Dabob Bay During October 1966, and their Implications on Acoustic Weapons Systems". - This will be issued as an NRL Formal Report.

Report of NRL Progress

1. "Environmental Reverberations Studies"(U) submitted Feb. 16, 1967.

2. "Environmental Reverberation Studies" (U) submitted 2 Feb 1967.

3. "Acoustic Countermeasure Techniques Investigation and Environmental Reverberation Studies" (C) Submitted 4 January 1967.

4. "Environmental Reverberation Studies" (U) Submitted 4 January 1967.

Fourth Navy Symposium on Military Oceanography 10-12 May 1967

Three Abstracts have been submitted, two by Branch Personnel and one by a private contractor on work he is doing for the Branch.

1. "Some Turbidimetric Observations in the East Siberian Sea During July-September 1964" (C).

2. "Analysis of a Particulate Sound Scattering Layer Observed at the Dabob Bay 3-D Range" (C).

3. "Microbubble Dynamics in the Ocean" (U)

Technical Talks

1. "Surface Ship Torpedo Countermeasures" - Acoustic and Torpedo Countermeasures Systems Workshop - NRL - March 1966.

2. "Particles in the Sea" - Research Reserve Officers Seminar - June 1966

CSR's

Total 34

Computer Programs - Designed and/or Run

1. Normal Mode Program run at Research Computation Center

   Version One: Propagation Loss, Depth Functions
   Version Two: Same as one plus Phase and Hanekl Functions Print Out

2. Program for correcting tapes of FORTRAN source program tapes.

3. FORTRAN Program for Wilson's Equation of sound speed in water.

4. FORTRAN Program for Schweitzer's equation for loss from the duct by surface scattering.

5. FORTRAN program for angle of arrival for Assured Range Study.

6. Machine language tape translator for any punched-tape codes to Bunker Ramo 133.

7. Assured Range data reducer for February 1967 trip.

8. Correction of velocity and attenuation due to undissolved gases.

9. Machine language Multiplexer and A/D Converter data tape punch.

10. FORTRAN multiplex data tape BCD and selector program.

11. FORTRAN language typewriter checker

12. LGP-30 Ray trace & loss (NRL).

13. PNL Ray Trace for Automatic Plotter

14. Modifications to Algebraic Compiler and Translator.

Contracts Monitored

1. Human Factors Research Corporation - "A Study to Determine the Characteristics of an Effective ASW Countermeasure Device."

2. Vitro Laboratories - "Acoustic Microbubble Spectrum Analyzer"

3. Coulter Corporation - " Model DS Coulter Counter"

This has turned into a COD proposition, the contract is as yet unsigned, but work is progressing.

4. Lier Siegler -"Optical Laser System to measure underwater backscatter from particulate matter".

5. Jalbert Aerology Laboratory - "Aerial Photographic Platform"

Propagation

1. Objectives

a) Sound Scattering in the Ocean -- Describe in mathematical terms the scattering of acoustic energy from the ocean bottom, volume and surface, and specify operational procedures to obtain optimum sonar performance where bottom and/or surface-scattered paths are used.

b) Sound Speeds in the Ocean -- Develop equations and program computational procedures to be used by operational forces for computing target range from sonar and environmental data, and determine the errors in target range resulting from, and develop methods for utilizing, the type of oceanographic and target data available to operating forces.

c) Signal Analysis -- Predict effect of oceanographic parameters on the characteristics of the acoustical signal, and develop requirements for signal design and signal processing to minimize the degrading effects of undesirable propagation path characteristics.

d) Shallow Water Propagation -- Describe in mathematical terms the interrelation of acoustic and oceanographic parameters in shallow water propagation.

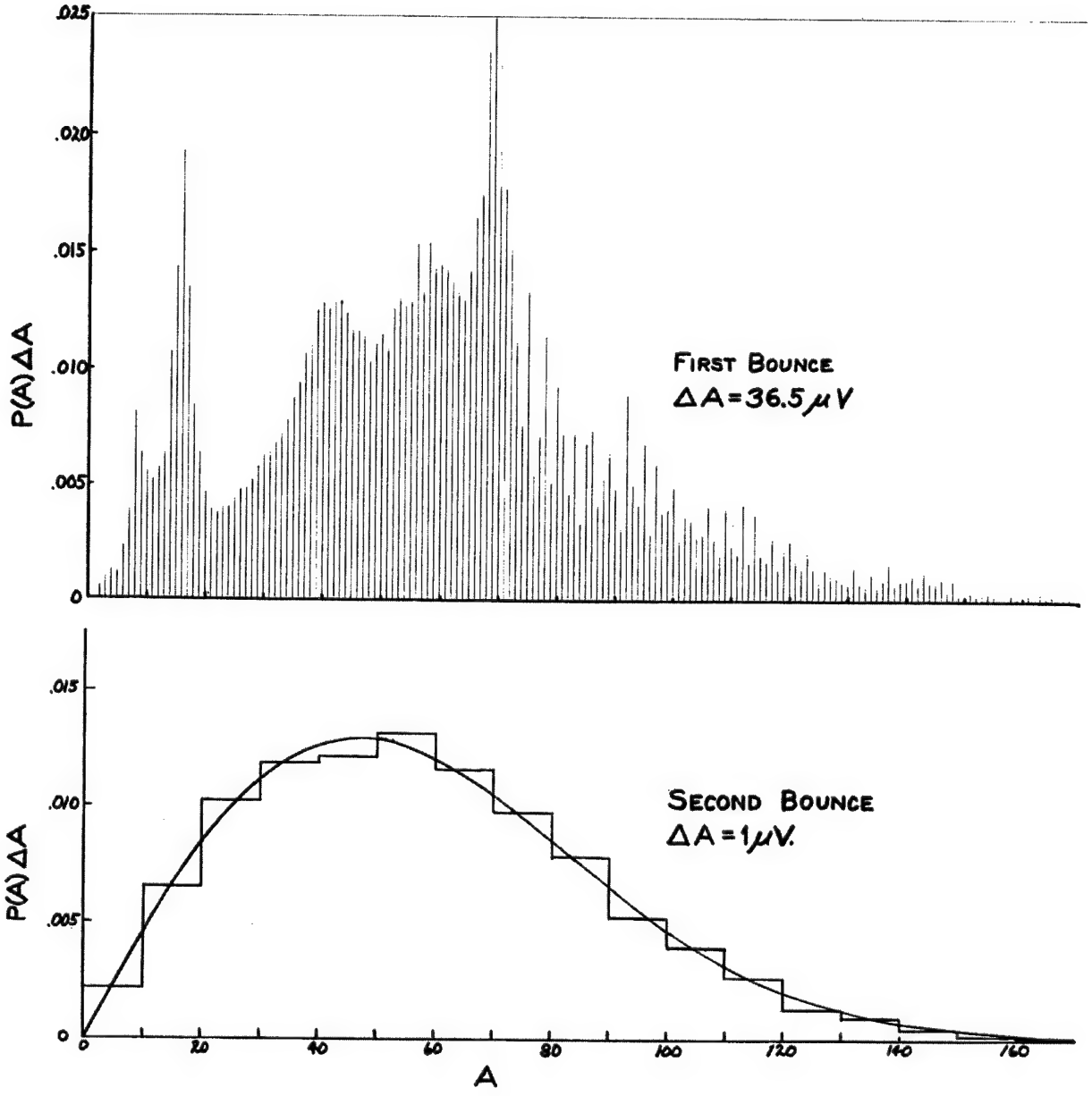
e) Sonar Transmitter Development -- Anticipate the future needs for sonar transmitters, meet these needs through continued research and development in new devices, system design and application to the sonar problem.

f) Project ARTEMIS -- Develop the technology for producing a high power low frequency acoustic source for the fixed ocean surveillance systems and to produce such a source for the propagation research program of Project ARTEMIS.

2. Productivity

a) Sound Scattering in the Ocean -- The measured density and distribution functions of bottom scattered signals are being compared with analytically computed functions for various parameters. Computer programs have been developed for obtaining and displaying density and distribution functions of the measured scatter returns. Preliminary results are illustrated in Figure 12a and 12b. Figure 12a is the density function for the signal returned from the bottom with the incident direction

AMPLITUDE DISTRIBUTIONS OF BOTTOM SCATTERED RETURNS



Figs. 12(a) & (b)

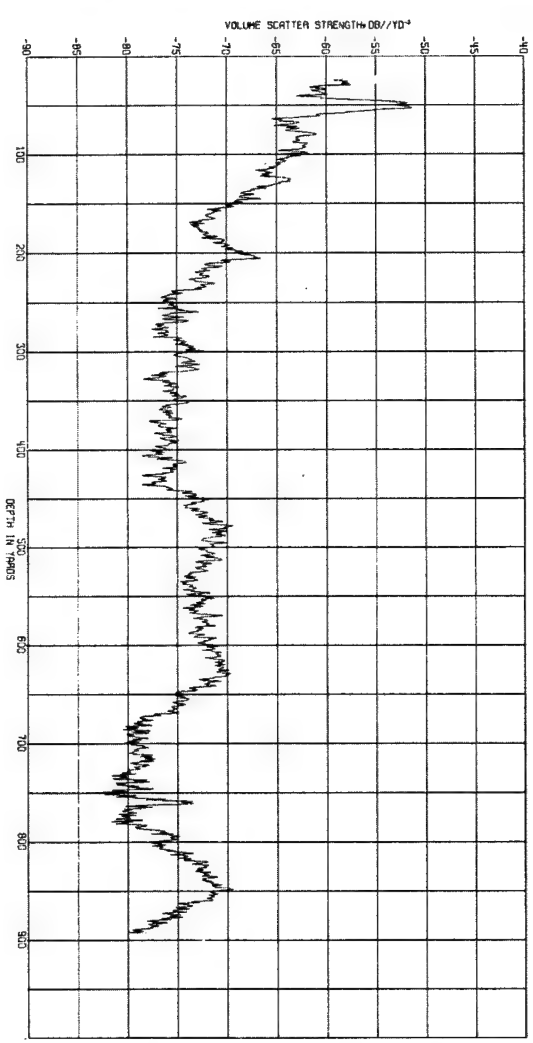
being 90°. The total number of samples is approximately 100,000 measurements. Figure 12b is the density function for the signal when it is scattered from the surface once and bottom twice, i.e., two bounces. Also included in 12b is a Raleigh distribution for comparison. Preliminary indications are that the structure of the density function, as illustrated by Figure 12a, changes with bottom grazing angle. Analytical distributions are being studied to provide a physical explanation of the nature of the measured distribution.

Computer programs have been devised for computing and displaying volume scattering strength as a function of depth. Figure 13 illustrates three examples of volume scattering strength profiles. Currently the profiles are being produced to enable a comparison as a function of the parameters, such as time of day, etc., of the experiment.

Analytical expressions have been obtained for the acoustic pressure and intensity of a composit source consisting of a number of simple (point source) sources. These expressions are applicable for the conditions of the composit source constructed from ordered simple sources and for composit sources constructed from statistically disordered (in space) simple sources. The expressions are valid for all parts of the field. The acoustic pressure and intensity of the field have been evaluated for a limited number of cases of ordered and disordered sources. Analytical expressions have been obtained for this expected pressure field (currently limited to far field cases) for sources perturbed according to several standard distributions. The expected pressure fields are currently being evaluated for representative cases.

b) Sound Speed in the Ocean -- The previous programs written in NELIAC language for NAREC computation have been re-constituted (combined NELIAC-Fortran) to run on the new CDC computer. These programs develop sound speed profiles utilizing temperature and salinity parameters versus depth and incorporates a correction for curved earth. The Acoustic Ray Trace provides a readout of range, travel time, mean horizontal sound speed, and propagation loss (spreading $dR/d\theta$ and attenuation) as a function of initial angle at the source or the vertex velocity. Acoustic point-to-point analysis is provided which, for a given single curvilinear profile and selected source and receiver depth and range, determines all the possible ray solutions incorporating paths involving the number of specified surface and bottom reflections. Programming underway will incorporate a linear segmented variable ocean bottom in place of the flat bottom description previously employed.

VOLUME SCATTERING PROFILES



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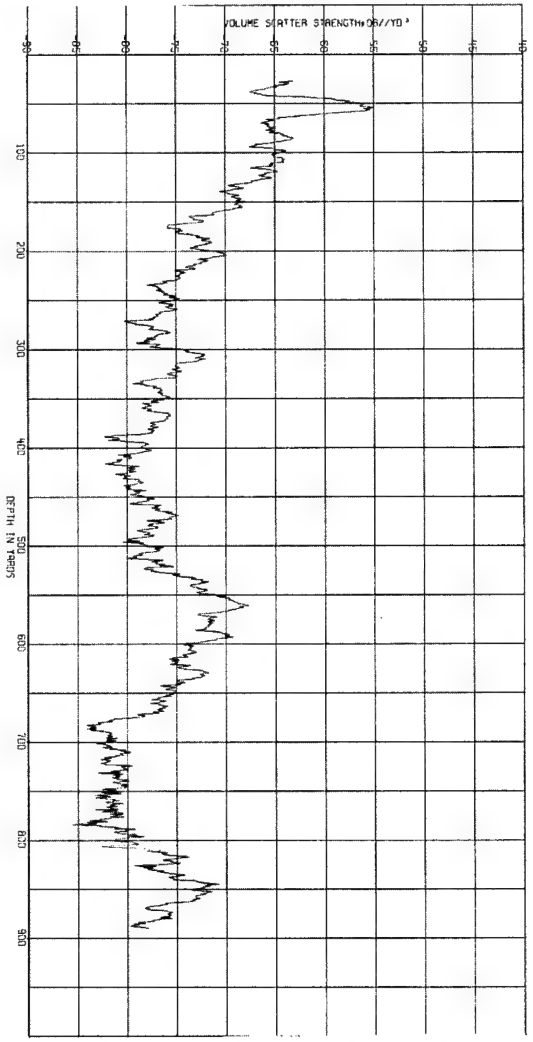
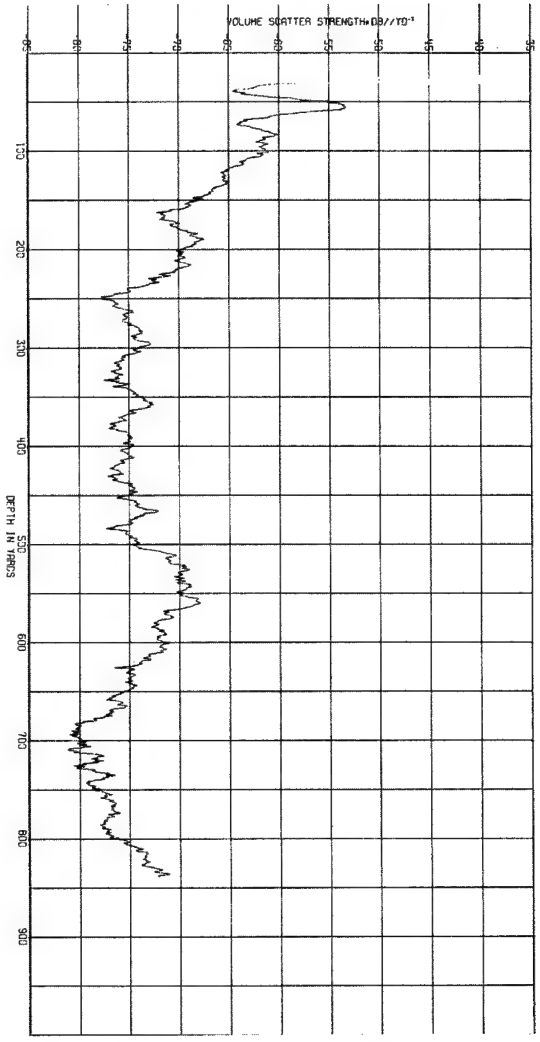


β=90° T=10ms.
T=22:09:50-13:50



β=70° T=10ms.
T=22:41:10-51:00

Fig. 13

One major field trip was undertaken during September-October 1966 to several areas in the Labrador Basin and Norwegian Sea (Fig. 14). This trip, conducted aboard the USNS SANDS and USNS LYNCH served the purposes of two problems, this one and 55SO1-23 which is to be described later.

Prior to the trip typical sound speed profiles for several of the areas to be visited were obtained for use in the NRL computer program to aid in selecting the suitable source and receiver depths for the several operating areas. From this it was determined that direct reflected paths including one surface reflection were possible out to certain ranges and that bottom refracted pulse trains were possible. In addition to this, convergence zone propagation did exist in a few of the areas. It was interesting to note that for one operating area computations indicated 16 separate arrivals could be expected at a range of 42 kyds. between source and receiver. At 40 kyds. 38 ray path solutions were obtained with no more than one bottom reflection.

A summary of the characteristics of the areas visited along with the environmental and acoustic data is presented in Table 2. No data was obtained from Area 2 as the original 750 cps and 1500 cps transducer was lost in this area. This unit was replaced by a 750 unit which was used throughout the remaining 5 areas.

The reduction of data from all field trips is in progress. This includes data obtained west of Bermuda and on the rise south of Bermuda, Charleston rise, off Grand Turk and Puerto Rico, and data obtained on the 1966 trip to the Labrador Basin and Norwegian Sea. An analysis has been made showing the contributions of uncertain geometry and sound speed to the range error estimates as derived for an isovelocity model of the sound speed depth profile. The uncertainties considered were sound speed depth profile, travel time, water depth, bottom slope, source and target depths.

c) Signal Analysis -- A field experiment was conducted in Septermber and October 1966 in the Labrador Basin and Norwegian Sea. The purpose of the experiment was to obtain information concerning the envelope structure and temporal stability of acoustic signals which had

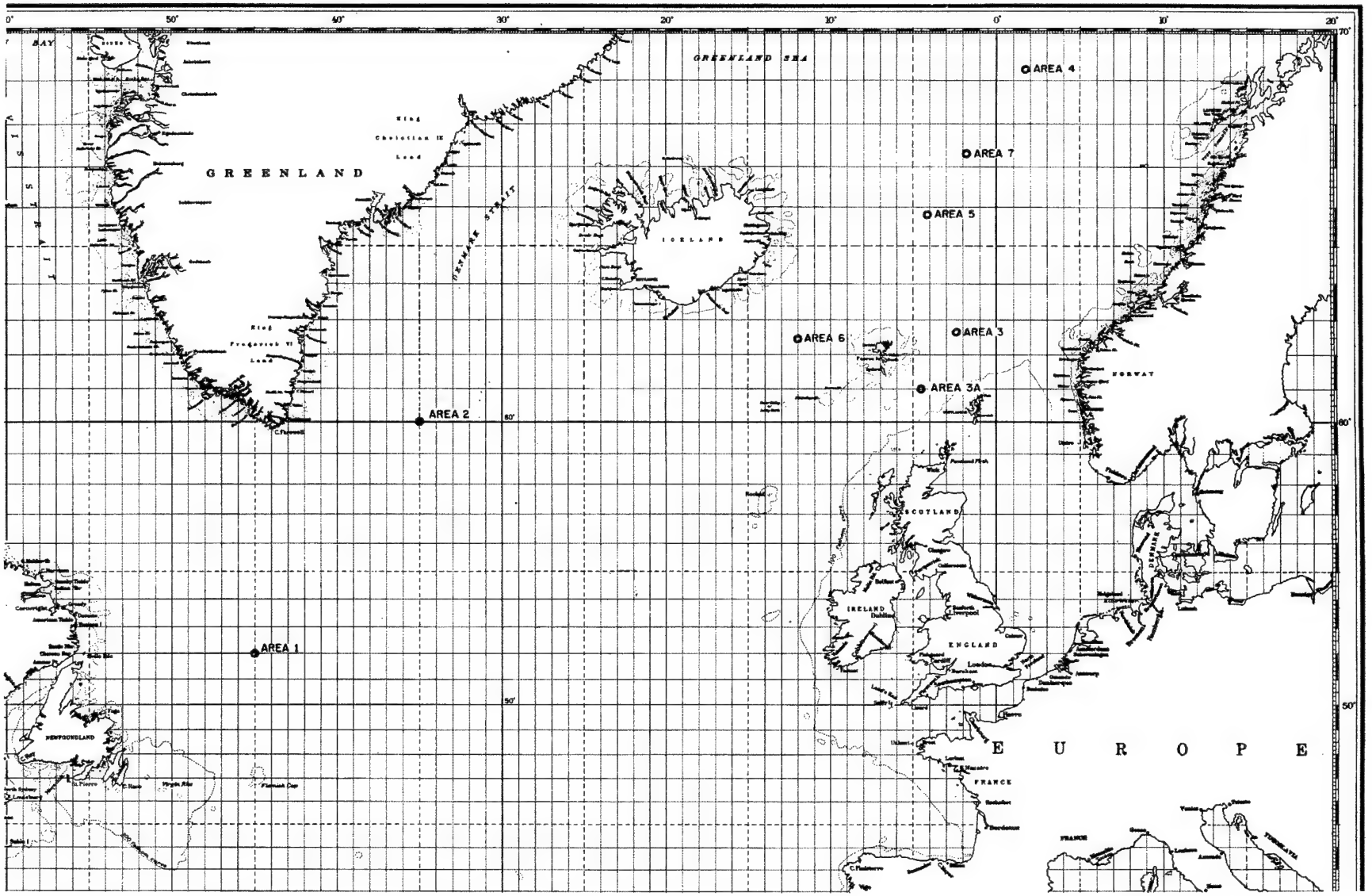


Fig. 14 -- POSITION CHART FOR CRUISE

TABLE 2

SUMMARY OF NRL CRUISE 601-67 (USNS SANDS), 701-67 (USNS LYNCH)
NRL PROBLEMS 55S01-15 and 55S01-23

	AREA					
	1	3	3A	4	5	7
Latitude	52° 00' N	62° 40' N	61° 01' N	69° 15' N	65° 50' N	67° 20' N
Longitude	45° 00' W	2° 50' W	4° 28' W	1° 35' E	4° 10' W	1° 45' W
Water Depth (Fath)	2340	1650	630	1710	2020	1680
Bottom Description	Basin	Continental rise	Continental rise	Basin	Abyssal Hills	Basin
Slope	0°-0.3°	1°-3°	0°-0.3°	0°-0.3°	irregular	0°-0.3°
Type	mud/sand	mud	mud/sand	mud	mud	mud
No. of Cores	2	1	1	1	1	1
No. of Deep Velocimeter	0	1	1	1	1	1
No. of Subbottom Profiles	1	2	0	2	1	2
Frequency, cps	750/1500	750	750	750	750	750
Ranges, Kyd.	9-36	3-6	3-4	7-46	3-37	7-40
Source, depth, ft.	300, 600	1000	250	300, 600	300,600	300, 600, 1000
Hyd. depth, ft.	300-2000	300-2000	500	300-2000	300-2000	300-2000
Prop. Paths	direct	direct	direct	direct	direct	direct
	bottom bounce	bottom bounce	bottom bounce	bottom bounce	bottom bounce	bottom bounce
		(1st & 2nd)	(1st & 2nd)	convergence	convergence	convergence

been reflected from the ocean bottom and surface. Experiments were conducted in six different areas having a variety of bottom types. In area 1, 750 Hz and 1500 Hz were used. In areas 3 to 7, 750 Hz signal only was employed. Magnetic tape recordings of the received signals were obtained for processing in the Laboratory.

Processing of the data obtained on this field trip has been initiated and computer programs have been written to perform cross-correlations between arrival envelopes at selected intervals of time. Approximately ten percent of the data has been processed in this manner. Examples of received signal envelopes are shown Fig. 15 ~~and 16~~. Two groups of five consecutive arrivals are illustrated. The pulse repetition rate was 10 seconds. Density functions for the peak amplitudes of each of the four principal paths have been plotted for 173 consecutive transmissions in an area in the Norwegian Sea. The mean peak intensity for the path which contains one bottom and no surface reflections is -18.2 decibels relative to the peak intensity obtained by subtracting spherical spreading loss from the transmitted source level. The three paths involving one or more surface reflections as well as a bottom reflection all exhibited a smaller mean loss than for the bottom-only path, the bottom-surface path having nearly five decibels less loss than the bottom-only path. Although the peak amplitude scatter is approximately the same for all four paths there is a marked difference in the rate of change of peak amplitude with time of the scatter. The peak amplitude of the bottom-only path varies slowly whereas paths involving a surface reflection exhibit wide fluctuations from ping to ping. The temporal stability of envelope structure for the four path ensemble for a shorter run in the same area is illustrated in Fig. 17. Each point on the curve is the result of averaging at least thrity cross-correlations between arrival envelopes separated by appropriate time intervals. For example, the point plotted at 150 seconds represents the average peak value of 30 cross-correlations between the envelopes of bottom-bounce arrivals, where each pair of arrivals was separated in time by 150 seconds.

A study of instrumentation requirements for future work is being performed. It is anticipated that future experiments will require the use of very broad band-width, i.e., 1000 Hz or greater, doppler insensitive signals,

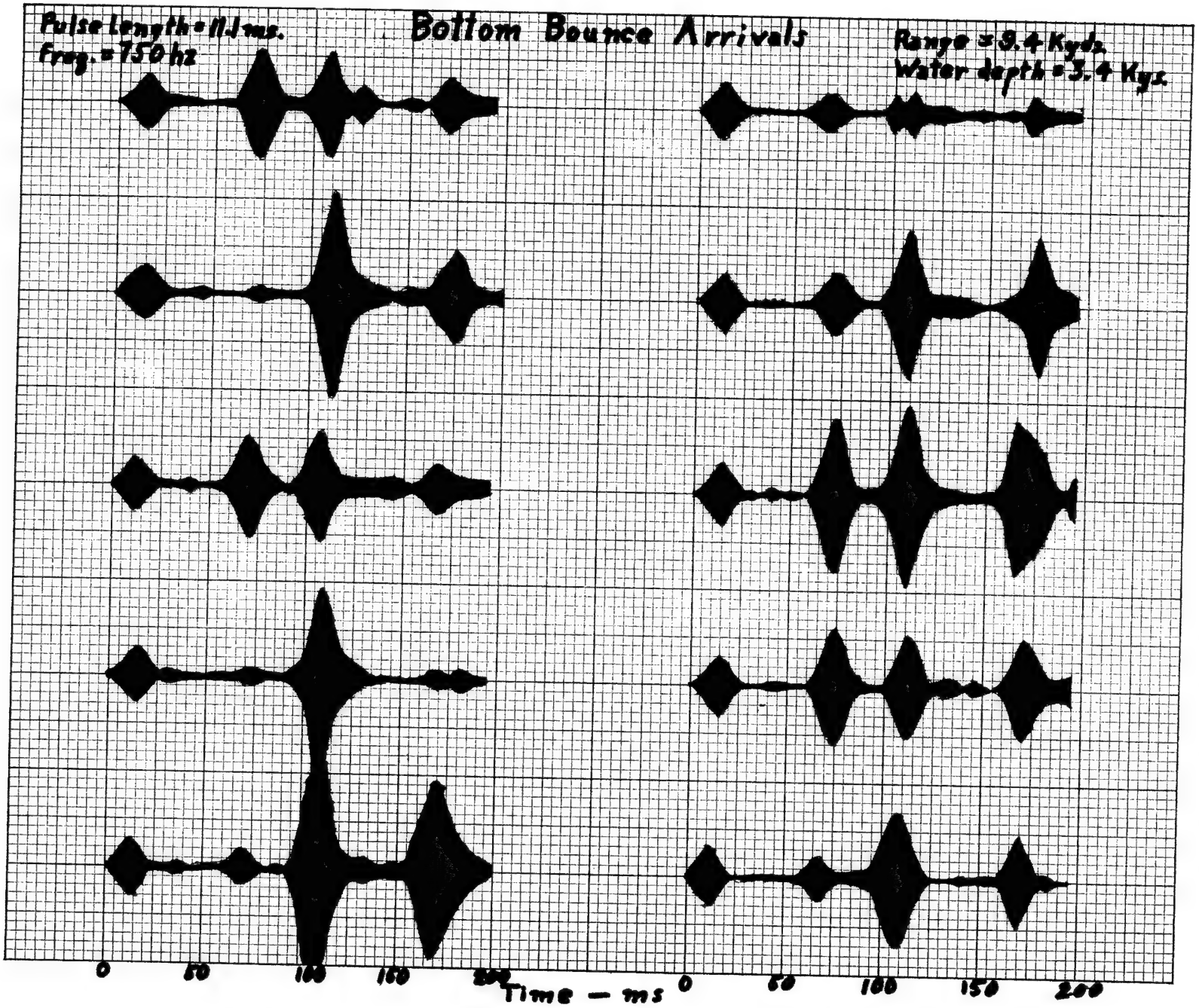


Fig. 15 -- SIGNALS REFLECTED FROM THE BOTTOM

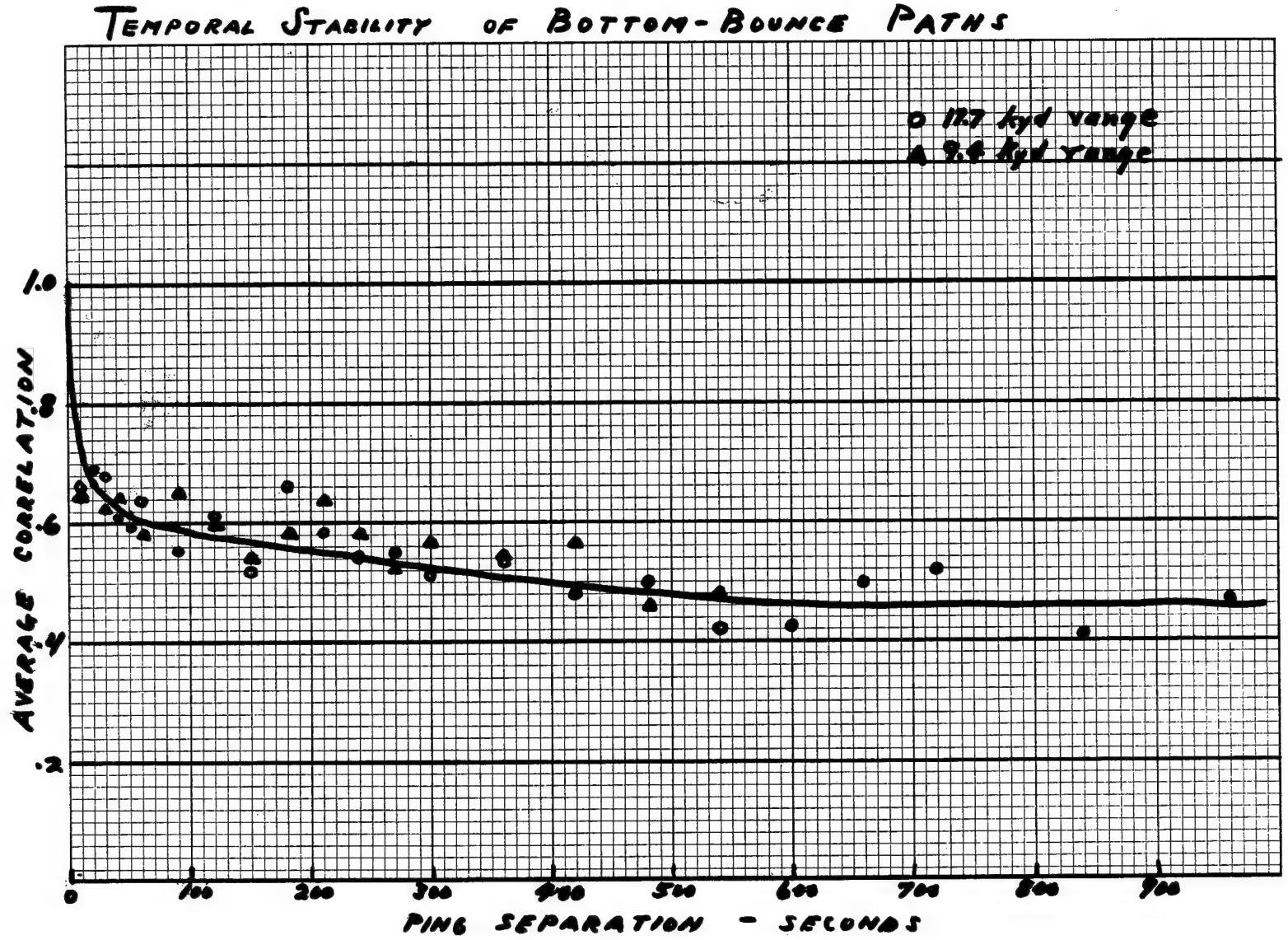


Fig. 17

ENVELOPE CORRELATION OF
MULTI-PATH ARRIVALS

and linear analog correlators. New instrumentation requirements include a precision tape recorder and two eight-thousand-word core memory banks.

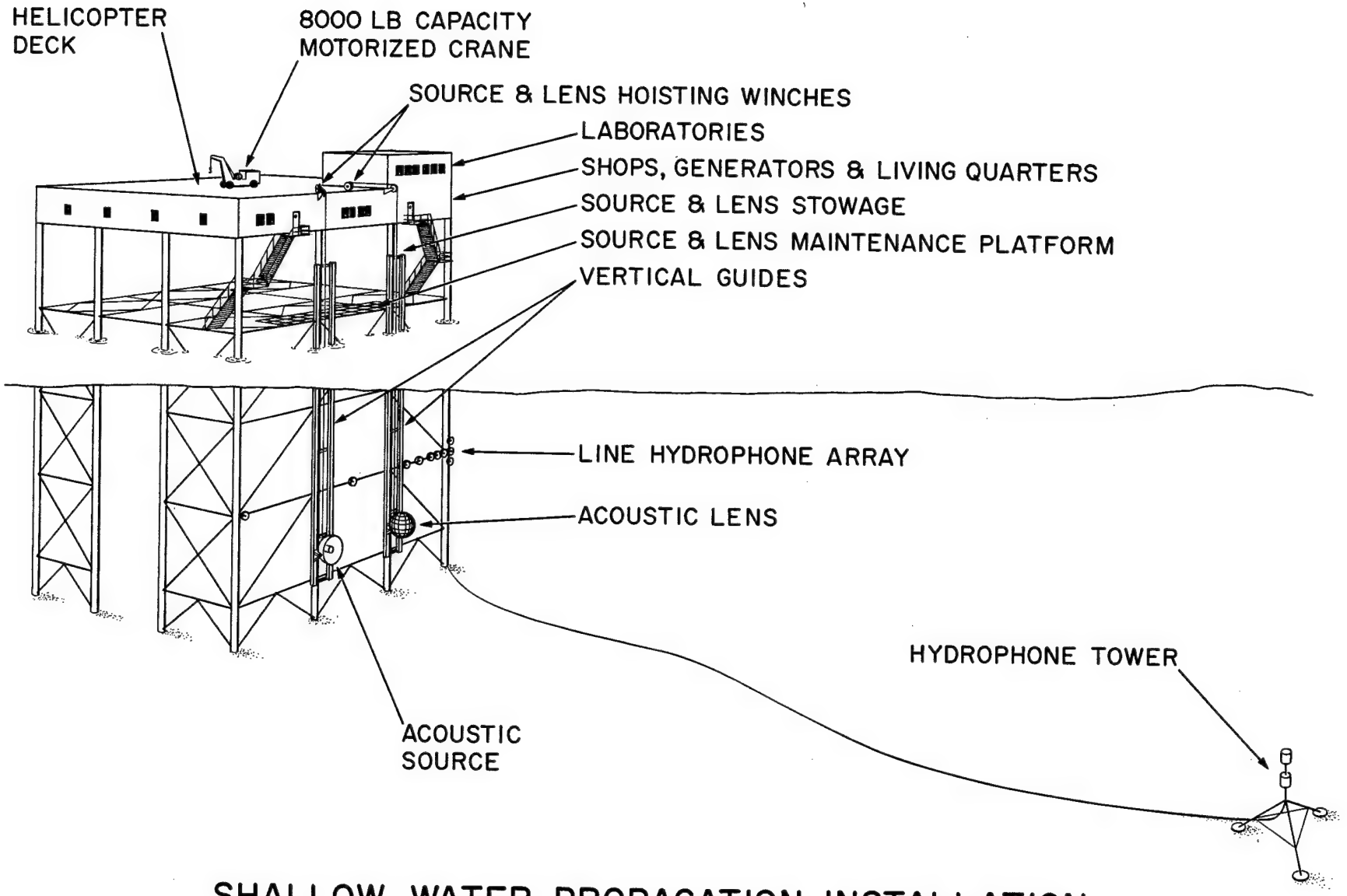
d) Shallow Water Propagation -- Plans are being formulated for the experimental work to support this program. It is the intention that a fixed installation site shall be utilized for making measurements in order to retain an identical geometry of the acoustic system relative to the fixed environmental parameters. By so doing it will be possible to determine the interaction between acoustics of the medium and the time and spatial varying environmental parameters.

The purpose of the experimental program will be to determine the variability of the following parameters with the environment. (1) Acoustic field: level, phase and acoustic stability, and spatial distribution. (2) Reverberation: level, spatial and temporal coherence, and direction. (3) Noise: level and direction.

The instrumentation system required to measure the above quantities is now being determined. An acoustic source utilizing a transducer with a 10° conical beam and a bandwidth from 2200-3600 cps will be utilized. The back scattered signals will be detected with several hydrophones as well as with a narrow-beam receiving system. The signal-field intensity will be measured with a line of hydrophones suspended from a surface ship. The same instrumentation used for making reverberation measurements will also be used for making noise measurements.

Plans have been made to utilize a shallow water site off Panama City where the Mine Defense Laboratory has an off-shore platform, known as STAGE 1. MDL has offered the use of this facility and will cooperate by providing support. The setup at STAGE 1 is shown diagramatically in Fig. 18.

e) Sonar Transmitter Development -- The common-collector circuit designed prior to this report period has been used in a field application. This includes two of the units, each rated 1200 watts output being used at the Underwater Sound Reference Division, Orlando, Florida, and a system consisting of 18 of the units rated 20 kw output used by the Sound Division in propagation measurements at sea. This system was installed abroad the USNS LYNCH, T-AGOR 7, and used to power a magnetostrictive



SHALLOW WATER PROPAGATION INSTALLATION

Fig. 18

transducer with both sine and phase-modulated sequences both on a pulse basis and in CW. Maximum output level was 15 KVA. Successful operation at 21 KVA was achieved for short periods; power supply limitations precluded lengthy operation at this level. The DC supply voltage for these amplifiers is 30 volts.

In an attempt to extend the upper frequency limit of the above amplifier a breadboard version of the output stage was designed using DTS 423 transistors. The high frequency response was extended from 3 kHz for the above amplifier to 10 kHz. Sufficient information was obtained to indicate that the circuit is usable for 10 kHz systems.

f) Project ARTEMIS -- A definition of design parameters for the ARTEMIS high power acoustic source remains as unfinished business. Equipment was constructed to correlate the significant characteristics of compliant spheres which were to be placed in a uniform underwater acoustic field. Having such information, predictions of the effects of inserting such bodies into a field could be made, and more directly, criteria for the design of practical compliant underwater acoustic reflectors established.

Thin walled seamless plastic spheres of 1/2 - 1 inch diameter, of various wall thickness down to a few mils were cast in a rotational casting device which was designed and built specifically for the purpose. The pliable spheres were tested for compressibility and found to be as much as 104 times as compressible as water. The compressibility depends upon diameter, wall thickness and material. One-sixteenth inch diameter plastic tubing was bonded to the spheres so that the latter could be pressurized at test depth. The spheres were affixed within test racks of negligible mass constructed of 1/16 inch diameter brass tubing, hollow cylindrical pressure probes were juxtaposed with the spheres at discrete distances from them. Experimental data shows the pressure in the vicinity of the thin walled 1 inch sphere. The spread in data is considered excessive and is thought to be the result of inaccuracies in the measurement of distance between sphere and probe. Single probes which can be moved away from the spheres with continuous and known progression will be used in the future to reduce the spread problem and the inherent inaccuracies in making measurement with a number of probes placed in different positions around the spheres.

3. Future Plans

a) Sound Scattering in the Ocean -- The present effort to extract and analyze the field trip data is not complete. This effort will be continued. The approach will be along the same general lines as that indicated in the results reported to date. As part of this program an attempt will be made to obtain the field statistics of surface scattering and to obtain the three dimensional field of scattering from the sea surface.

A transducer mount, for installation in USS GROUPER, that will enable the acquisition of scattering, data in the frequency range of 3.5 to 20 kHz, has been delivered and is being tested at Lake Seneca. A field trip to the Blake Plateau will use this transducer in November. Reports on Scattering from the Ocean Bottom in the Bermuda Area; and Three Dimensional Scattered Fields from the Ocean Bottom are planned for July 1967.

b) Sound Speed in the Ocean -- The theoretical phase will include completion of a new Fortran ray trace program incorporating a variable bottom with multiple sound speed profiles. It will incorporate multiple sound speed profiles, and variable bottom features in a point-to-point analysis, with horizontal range as an input.

Extraction and analysis of experimental data will be completed for the areas near Puerto Rico-Grand Turk, west of Bermuda, the rise south of Bermuda, Labrador Basin and Norwegian Sea. A special study will be made for a few selected areas to ascertain the effect of environment on target range prediction accuracy and to develop a simple and practical model for operational use by the fleet.

Reports will cover the region from the Grand Turk to the Blake Plateau, a region west of Bermuda and the rise south of Bermuda and off Charleston, and some of the bottom provinces of the Labrador Basin and Norwegian Sea. Included will be comparisons between experimental data and theoretical computations using refracted rays and the straight line rays. A final report will include utility of a simplified model for operational use by the fleet. The problem will be terminated at the end of FY 68.

c) Signal Analysis - Extraction and processing of the field trip data will be continued and completed during the next several months. The analysis will be in general along the line indicated by the work to date.

Preparation will be made for another field experiment which is intended for the shallow water fixed installation site being developed in connection with 55SO1-33. The purpose of these experiments will be to study the effect of sea conditions on the surface-reflected acoustic wave. This is required to clarify the results obtained in the September-October 1966 field trip where propagation paths including the surface and bottom paths were investigated. This fixed installation will also serve for the evaluation of instrumentation being developed to record and process the received acoustic signals.

d) Shallow Water Propagation -- Specifications for the instrumentation system will be completed and procurement of components initiated. An existing computer program utilizing ray trace theory will be used to determine results to be expected from propagation at the STAGE 1 off-shore platform. Wave theory will be introduced and put into a computer program so that this model can be prepared for this experimental area.

The acoustic source receiving array and acoustic instrumentation will be installed at the off-shore platform in August and data obtained as soon as work can be completed. Measurements with the service ship over the ensonified area will be made next January.

e) Sonar Transmitter Development -- A final report on power amplifier development which is now in preparation will be concluded by June 1967. This program has been very effective throughout its entire duration. However, termination of the work at this point should not be construed to mean that the problems have all been solved. Problem areas do remain and should be under continuing investigation. Since the work does not fit in the Branch program, the effort will be terminated with the completion of the above report and the person assigned to this work transferred to another area. Experience gained on this problem will be utilized in providing acoustic sources for the Branch problems on propagation and in providing receiving instrumentation.

f) Project ARTEMIS -- The existing measurement program will be continued for another 6 to 10 months in order to obtain conclusive results from this program. It is not anticipated that this will satisfy the original objectives either for the ARTEMIS program or for the future requirements for deep directional transducers. However, the funding made available for this work out of the ARTEMIS program was inadequate to carry on the type of effort that would bring forth results in a few years. Because of these limited resources termination of the effort has been planned and the Branch personnel and Branch effort will be utilized in other areas.

[redacted]

23 March 1967

Committee Reports on the Progress of the
Sound Division's Propagation Branch

Committee Membership

The committee is composed of

Dr. H. L. Saxton, Chairman

Mr. Emerick Toth

Mr. H. L. Peterson

Mr. A. T. McClinton

This committee met on the afternoon of 23 March, following the presentation of the program in the morning by Mr. McClinton and his section heads.

Nature of the Work

Most of the work of this branch in its present phases is research, a quest for knowledge. This fact is recognized by NAVSHIPS which provides most of the support. All funds are 6.2. Later phases may become development. Research is usually long-range and its contribution to Navy needs is not immediate. However, future application to present problems seems certain since the Navy has a serious need for just the kind of knowledge that this branch is seeking.

Navy Need

Navy planning includes future generations of sonars which seem essential to ASW and to the prosubmarine program. Hundreds of

[redacted]

[redacted]

millions of dollars are expected to be spent in design and development. Yet no real understanding exists of the mechanisms involved in bottom-bounce and shallow water propagation including, in a general sense, both forward and backward scattering and multipath complications. Without such knowledge, design is on an unfirm basis.

This branch is aiming its research more and more toward the general scattering problem with establishment of mathematical models that will permit prediction of levels of signal and reverberation fields and of signal distortion that may impair coherent detection.

The problem "Sound Speeds in the Ocean" is directly related to determining range accuracy and means of improving it. This information is essential to weapon development programs. This problem is nearing completion and is being phased out.

Problems "Sound Scattering in the Ocean" and "Signal Analysis" are active problems aimed at acquiring knowledge and establishing useful mathematical models. Both may lead into signal design and processing. These two problems are cohesive to each other.

"Shallow Water Propagation" is an area judged most in need of increasing effort by the Signal Physics Committee. This Laboratory is accordingly shifting effort in this direction in a task completely cohesive with the other continuing major problems.

[redacted]

[redacted]

The three major continuing problems fit naturally into the Propagation Branch.

Attack on the Problems

The directions in which these problems are headed appear to the committee to be logical. They constitute a good balance between theory and experiment. The major problems relate to propagation in the ocean and require field trips. The field trips have been adequate in number and have been long enough to permit obtaining significant data. The data obtained have been or are being adequately analyzed.

A recent field trip in which several stations were occupied in the North Atlantic Ocean and Norweign Sea pointed up the following difficulties:

a. The AGOR's 6 and 7 are not stable enough to permit assured operation in northern waters.

b. Backup equipment is essential to assure continuity of the work in cases of equipment failure or losses. On this trip an assembly of 2 transducers at 750 Hz and 1500 Hz was lost early in the trip. The group responded immediately to the emergency and were able to obtain only a 750 Hz transducer for a continuation of the work. Provision of backup material is limited by funding.

Reports with dates are listed in Table I, along with other pertinent information.

[redacted]

[redacted]

Uniqueness of the Program

While inquiries continue to be made at higher levels concerning the possibility of duplication of the effort, undesirable duplication of the effort is practically non existent in the field of underwater acoustics. Extensive committee structure (too extensive perhaps) brings together project leaders from different laboratories for the study of the overall program in acoustics. This results in general appreciation of work being carried out elsewhere and of areas particularly in need of attention.

Work on bottom scattering was initiated here and is completely unique. The work on horizontal sound speed was assigned to this Laboratory in response to our proposal which we made to fill an urgent need for information for SUBROC. The Signal Analysis Problem is using the unique approach of observing distortion in signals and loss at each interface. This Laboratory's shallow water problem was initiated at a time when no work had been done in shallow water from fixed platforms.

Adequacy of Support

The requirement for major procurement items provides a buffer to insure against complete collapse of the problem when funding is less than requested. In general funding has been less than requested and this has resulted in a retardation of the work schedule. For 1968, funding by NAVSHIPS is increased. A

[redacted]

[redacted]

slight increase in ONR general funds is also required to assure progress at full potential of present personnel.

More personnel would of course speed up the prosecution of this branch's problems. However, the program is fitted to personnel on board. The greatest need for personnel is for Physicists with Ph. D.'s. An offer has gone out to one promising candidate. Attempts have been made to obtain the services of one of the leaders in the field of shallow water propagation. A third Ph. D., in the area of signal processing, would be helpful.

Conclusions

a. The committee finds no flaws in the selection of program or the planning which goes in its prosecution.

b. Personnel are adequate except that there is a need for additional theoretical help which would warrant the accession of up to 3 Ph. D.s.

c. Reporting in the past year has been adequate.

d. The funding requested in the latest A1 forms is realistic and is needed to insure no retardation in the rate of prosecution of the problems.

[redacted]

PROPAGATION BRANCH REPORTS

Title	No. Pages	No. Tables	No. Figures	Comments
H. L. Saxton, K. P. Thompson; "Divergence Loss to Target Below Duct for Certain Profiles"; NRL Memo Report 1671; 4 Jan 1966 (Conf)	23	1	29	Effect of source and target location on propagation loss relative to the near surface temperature depth profile.
B. G. Hurdle; "The Fine Structure of Acoustic Fields Scattered from the Ocean Bottom"; JASA ltr to editor, Vol. 40, No. 1, July 1966, p. 255	2	-	5	Introduces "near field concept" as a cause for amplitude fluctuations in ocean bottom scattered signals.
B. G. Hurdle, K. D. Flowers; "Effect of Geometry on Acoustic Monostatic Scattering from the Ocean"; NRL Report 6517	36	1	21	Compares isotropic scattering model to field data of the back scattered signal from the ocean bottom.
B. G. Hurdle, K. D. Flowers; "Monostatic Acoustic Scattering from the Ocean Volume"; NRL Report 6533	18	-	8	Compares isotropic scattering model to field data of the back scattered signal from the ocean volume and shows scattering strength to be independent of ensonified volume.
A. T. McClinton, J. Cybulski; "Target Range Prediction"; Proceedings of the 24th Navy Symposium on Underwater Acoustics; Dec. 1966	12	1	6	Presents analysis of acoustic geometry and sound speed depth profile uncertainty on target range prediction error.
R. H. Ferris, F. L. Hunsicker; "Power Limitations and Fidelity of Acoustic Sources"; NRL Memo Report 1730; Nov. 1966 (Conf)	50	3	21	Presents data on signal distortion attributable to one specific acoustic source and shows the affect of signals containing more than one frequency on transducer internal stresses.
W. M. Lawson, Jr.; "Linear Class B Audio Amplifier Output-Power Capability; Analysis of Load Impedance and Waveform Effects"; NRL Report 6379, Apr 1966.	16	-	8	Analyzes the effect of signal wave form and load impedance on amplifier output power capability.
W. M. Lawson, Jr.; "Sonar Transmitter Development"; Report of NRL Progress, Problem Notes, May 1966	2	-	-	Summary of Report 6379 above.

Table I

PROPAGATION BRANCH REPORTS (Cont)

Title	No. Pages	No. Tables	No. Figures	Comments
A. T. McClinton; "Project ARTEMIS Handbook, Vol. 1, Acoustic Source"; ARTEMIS Report 53, Vol. 1, Hudson Labs., 25 April 1966 (Conf)	177	3	72	A final report on the Project ARTEMIS acoustic source summarizing development history, technical description of systems considered and final system, and presentation of technical considerations for future systems.
R. H. Ferris, C. R. Rollins; "Project ARTEMIS Acoustic Source Performance Characteristics"; NRL Report 6534, (Conf)	35[1]	3	67	Description of acoustic performance characteristics of Project ARTEMIS source.
A. T. McClinton; "Project ARTEMIS Acoustic Source Summary Report"; NRL Report 6535 (Conf)	177[1]	3	72	Essentially the same as the Handbook above.

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Table I (Cont)

[1] Double spaced draft of text as submitted to TID Editorial Branch.

B. ADMINISTRATIVE FACTORS

I. Space

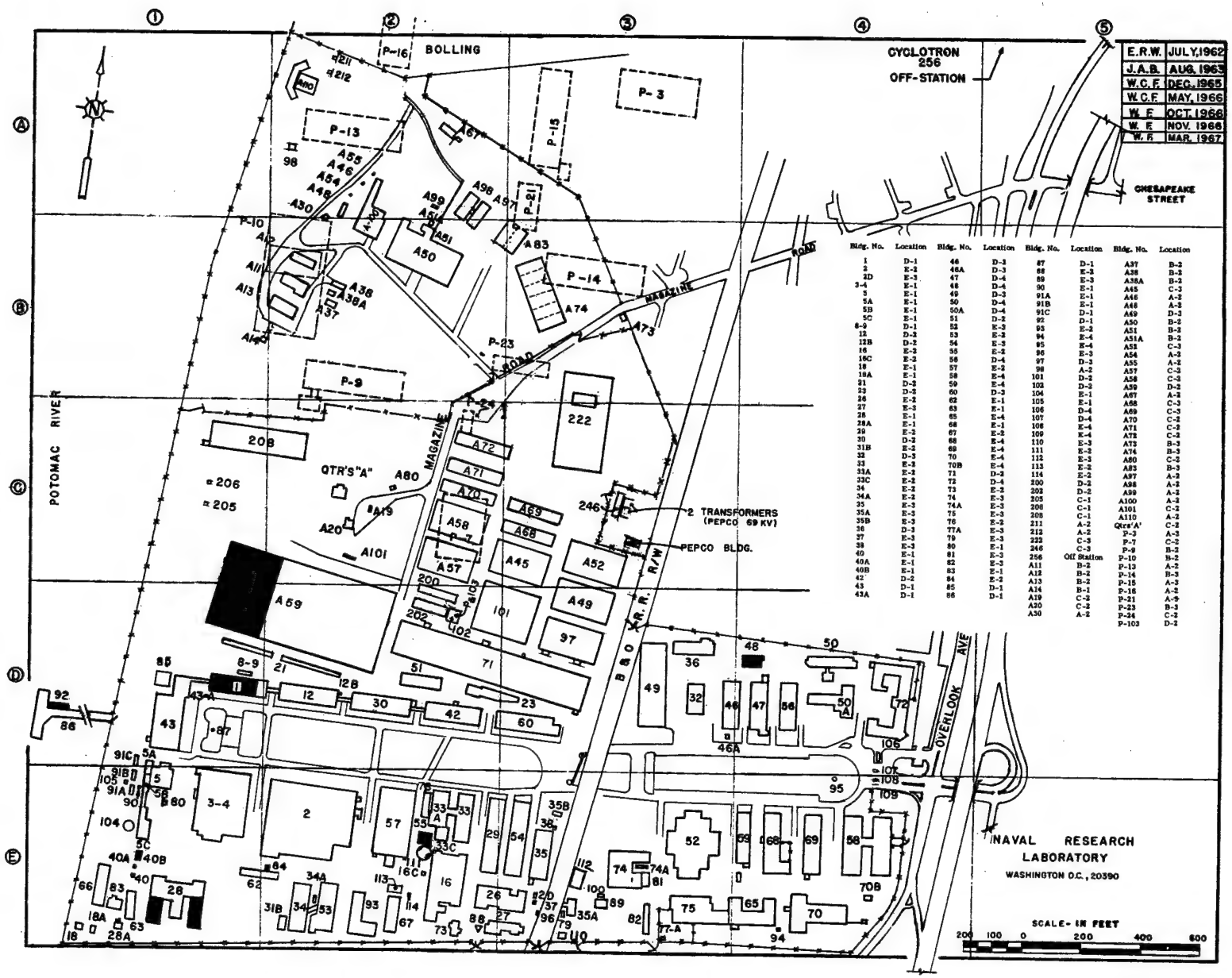
Fig. 19 is a map of the Laboratory with the areas occupied by the Sound Division in black. Table III specifies the use of each designated area. Because of the wide spacing of the areas, some areas are congested. These are Code 5560 in Building 1 and 5510 in Buildings 1 and 55. Relief will be afforded when the balance of the first and second floors of Building 1 is turned over to the Sound Division. This would be particularly relieving if Adm. Leydon's office were made available as a Division Office permitting Code 5560 to expand into the present Division administrative area.

The land at Dresden, New York, on which the NRLTCF shore station is situated, is leased. Purchase is presently provided for in Milcon 69. This will afford a long-term saving.

Potomac River barge is to be relinquished on completion of staging area in A-59. Processing of the tank for this area has lagged in Public Works for several months leading to a Sound Division request to retain the barge throughout this calendar year.

If Building 43 in its entirety were acquired, the Sound Division would consolidate in this building all the division effort now housed in Buildings 1, 28 and 40B. When the conversion of A-59, now in Milcon 69, is completed, Buildings 48 and 55 can be relinquished. The anechoic pressure tank control space will be in A-59. The whole Sound Division in Washington would then by congregated in 43 and A-59, with the anechoic pressure tank adjoining A-59. There would be room for moderate division expansion as discussed later.

Interest in Building 43 does not reflect lack of interest in a new building. In the planning of the plant expansion program for NRL, the Sound Division indicated its need for two buildings, one including a huge water tank and staging area. Development of A-59, as proposed and as contained in Milcon 69, would substitute for the requirement of the tank building.



Bldg. No.	Location	Bldg. No.	Location	Bldg. No.	Location	Bldg. No.	Location
1	D-1	46	D-3	87	D-1	A37	B-2
2	E-2	46A	D-3	88	E-3	A38	B-2
2D	E-3	47	D-4	89	E-3	A38A	B-2
3-4	E-1	48	D-4	90	E-1	A45	C-2
5	E-1	49	D-3	91A	E-1	A46	A-2
5A	E-1	50	D-4	91B	E-1	A48	A-2
5B	E-1	50A	D-4	91C	D-1	A49	B-2
5C	E-1	51	D-2	92	D-1	A50	B-2
6-2	D-1	52	E-3	93	E-2	A51	B-2
12	D-2	53	E-3	94	E-4	A51A	B-2
12B	D-2	54	E-3	95	E-4	A55	C-2
16	E-2	55	E-2	96	E-3	A56	A-2
16C	E-2	56	D-4	97	D-2	A57	A-2
18	E-1	57	E-2	98	A-2	A58	C-2
18A	E-1	58	E-4	101	D-2	A59	C-2
21	D-2	59	E-4	102	D-2	A60	D-2
23	D-2	60	D-3	106	E-1	A67	A-2
26	E-2	62	E-1	105	E-1	A68	C-2
27	E-2	63	E-1	106	D-4	A69	C-2
28	E-1	65	E-4	107	D-4	A70	C-2
28A	E-1	66	E-1	108	E-4	A71	C-2
29	E-2	67	E-2	109	E-4	A72	C-2
30	D-2	68	E-4	110	E-3	A73	B-3
31B	E-2	69	E-4	111	E-3	A74	B-3
32	D-3	70	E-4	112	E-4	A80	C-2
33	E-2	70B	E-4	113	E-2	A83	B-3
33A	E-2	71	D-2	114	E-2	A97	A-2
33C	E-2	72	D-4	200	D-2	A98	A-2
34	E-2	73	E-2	202	D-2	A99	A-2
34A	E-2	74	E-3	205	C-1	A100	A-2
35	E-3	74A	E-3	206	C-1	A101	C-2
35A	E-3	75	E-3	208	C-1	A110	A-2
35B	E-3	76	E-2	211	A-2	Qtrs'A'	C-2
36	D-3	77A	E-3	212	A-2	P-3	A-3
37	E-3	79	E-3	222	C-3	P-7	C-2
38	E-3	80	E-1	246	C-3	P-9	B-2
40	E-1	81	E-3	256	Off Station	P-10	B-2
40A	E-1	82	E-3	A11	B-2	P-13	A-2
40B	E-1	83	E-1	A12	B-2	P-14	B-3
42	D-2	84	E-2	A13	B-2	P-15	A-2
43	D-1	85	D-1	A14	B-1	P-16	A-2
43A	D-1	86	D-1	A19	C-2	P-21	A-2
				A20	C-2	P-23	B-3
				A30	A-2	P-24	C-2
						P-103	D-2

Fig. 19

TABLE III

Buildings Occupied by Sound Division

	5500	5506	5510	5520	5530	5550	5560
Building 1	1	1	1	1	1		1
Building 28						1	
Building 40B				2			
Building 48				3			
Building 55			4				
Building 92				5			
Building A59	5			6			
Potomac River Barge *			8	8	8	8	8
NRLTCF*		7					

* Not shown on Map of Laboratory

Explanatory Coding Showing Principal Use

1. Division and Branch offices and laboratories
2. Staging area for Potomac River Barge
3. Hydrostatic Pressure Facility
4. Anechoic Chamber
5. Storage Area
6. Experimental Acoustic Research and Staging Tanks
7. Transducer Calibration Facility, Dresden, N. Y.
8. Staging Area

II. Facilities

a. NRLTCF at Dresden, New York, and on Seneca Lake

The original platform now called the Far-field Platform has had its equipment further integrated during the past year. A computer-programmer is on order and personnel have taken a course in its uses. A portable hut is readied to take the computer. Portability will permit utilization not only on the Far-field Platform but also on other platforms on Seneca Lake, or in Washington.

A railroad barge has been modified to provide a lighter for mobility in handling large loads. A crawler crane has been acquired which can load from the shore to the lighter or can run on the lighter for loading and unloading. Fig. 20 shows a view of the lighter with the crawler crane aboard. The lighter will receive further modifications and will be put into temporary service for near-field calibrations. It is being moored in 100 feet of water for this purpose.

The proposed and partially funded near-field platform is in the design study stage. It is proposed to equip it with two bays each capable of handling large loads. One of these bays will be capable of handling loads of 100 tons, acording to plan. A new policy regarding this platform is under discussion with NUSL. It is anticipated that their needs which greatly exceed our own with respect to weight and power can be satisfied with this platform and it is suggested that they foot part of the bill and become joint tenants with management remaining with NRL.

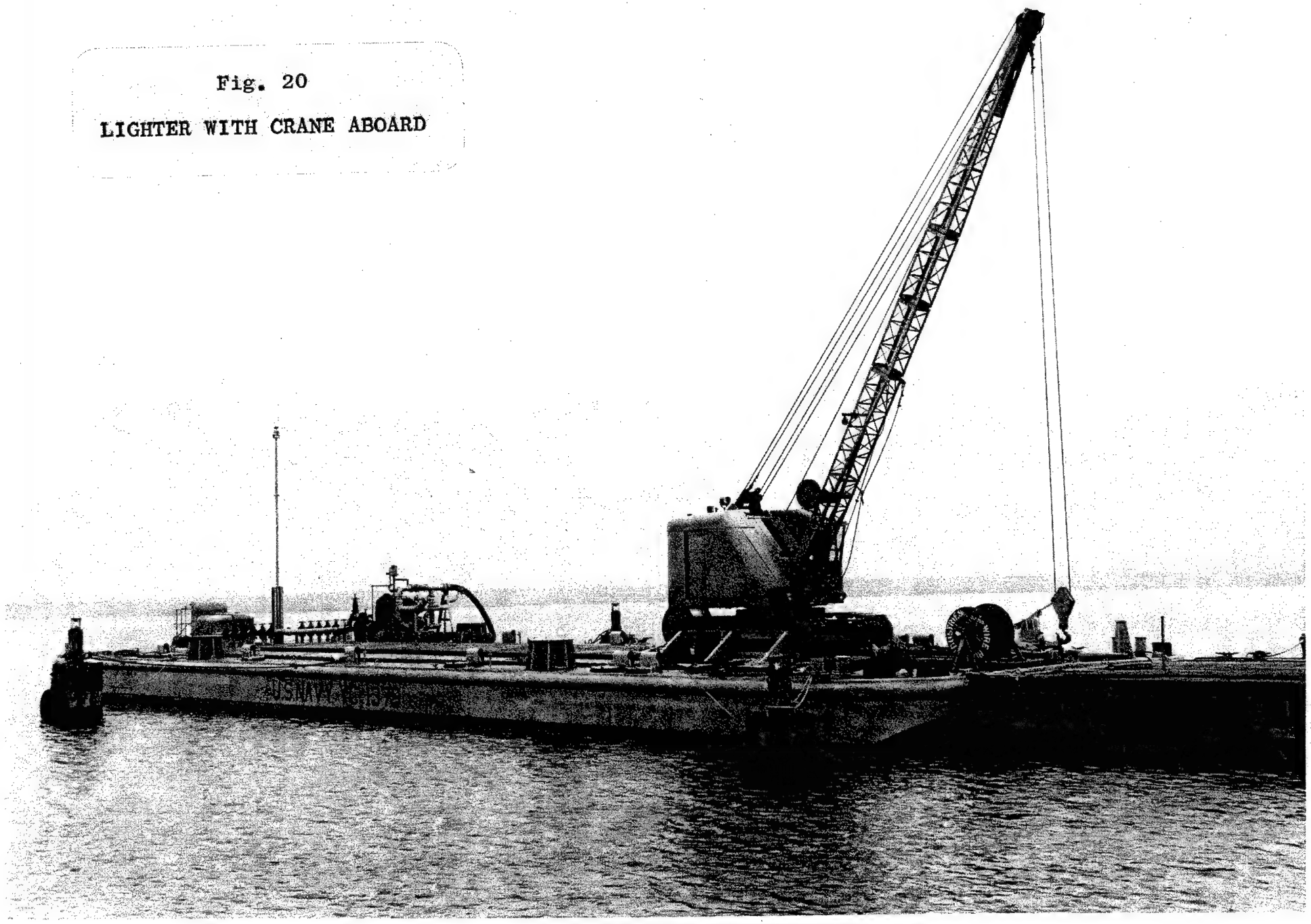
The shore site at Dresden contains three buildings. The originally leased building next to the dock has received increased service by those actually engaged in operations on the Lake, that is as part of a staging area. The office has been moved to the house on the hill top. The third building has served well for storage.

b. A-59 Development

The plan for major modification of A-59 to house most of the tank and pressure vessel facilities of the Sound Division is scheduled for carrying out in Milcon FY 69. During the past year, a large wooden tank with associated handling gear and electronic equipment has been acquired and put into operation. Fig. 5 is a view from above showing tank and handling equipment. This tank will

Fig. 20

LIGHTER WITH CRANE ABOARD



serve for far-field measurement at high frequency and for some near-field measurement at low frequency. Emphasis will be placed here on scale model studies and high precision measurements. A second tank has been requested for Building A-59 which would be a part of a staging area for field experiments. Delays by Public Works in getting started on this have resulted in several months delay. As a consequence it has been necessary to postpone relinquishing the Potomac River Barge to the end of calendar 67.

c. Large High-pressure Anechoic Vessel

The proposed vessel is included in Milcon 69. It is understood that considerable uncertainty exists at the level of ASNRD as to the need and the proper location. ASNRD has been furnished with answers to all questions, and a committee set up by DNL has recommended that the facility be located at NRL in Washington.

d. Other Pressure Tanks

There is presently no requirement for other new pressure tanks of large size. It is intended, however, to modify some of the present pressure tanks by lining them with anechoic material in order to permit acoustic work with transducers.

III. Problem Turnover

The termination of problem SO2-10, Sonar Transmitter Development, will be closed out at the end of this fiscal year. Manpower is being diverted to the shallow water problem. It is planned to terminate problem SO1-15, Sound Speeds in the Ocean, and Problem SO1-01, Ocean Sound Propagation, at the end of FY 68.

Problem SO1-33, Shallow Water Propagation, has been set up. During this fiscal year only ONR funds have been available. Delay in the provision of major funding by NSSC was occasioned by waiting for a committee on shallow water propagation to function. However, funding for FY 68 by NSSC is promised and ONR general funds can be slightly tapered off.

The desirability of reviving LORELI has been expressed by two subcommittees of the Undersea Warfare Mission Committee of the Director of Navy Laboratories. Lack of success in getting this project funded is discouraging. It appears that only by action of upper echelons in the Laboratory can anything be accomplished in this respect.

IV. Personnel

Fig. 21 gives the distribution of professional scientists in the Sound Division by grade, The cross-hatched bars represent the distribution of a year ago. The open bars represent the present. The latter provide terminal points which lie on a smooth, single-humped curve approaching more closely to the proposed ideal curve for the grade average ceiling imposed, as depicted by solidly shaded bars.

The staffing plan, if carried out would bring the distribution closer to ideal but would need to be supplemented by additional GS-7's in order to keep the grade average at or below ceiling.

Table IV gives a breakdown by class of all Division personnel.

Organization Unit	Professional	Technical	Clerical and Administrative	Wage Board
5500	3		5	
5506	1	2	1	5
5510	10	4	1	
5520	10	6	1	
5530	9	3	1	
5550	16	3	1	
5560	15	2	1	

TABLE IV

Personnel Breakdown

The Division personnel level remains at or close to the ceiling established for the Division. For many years,

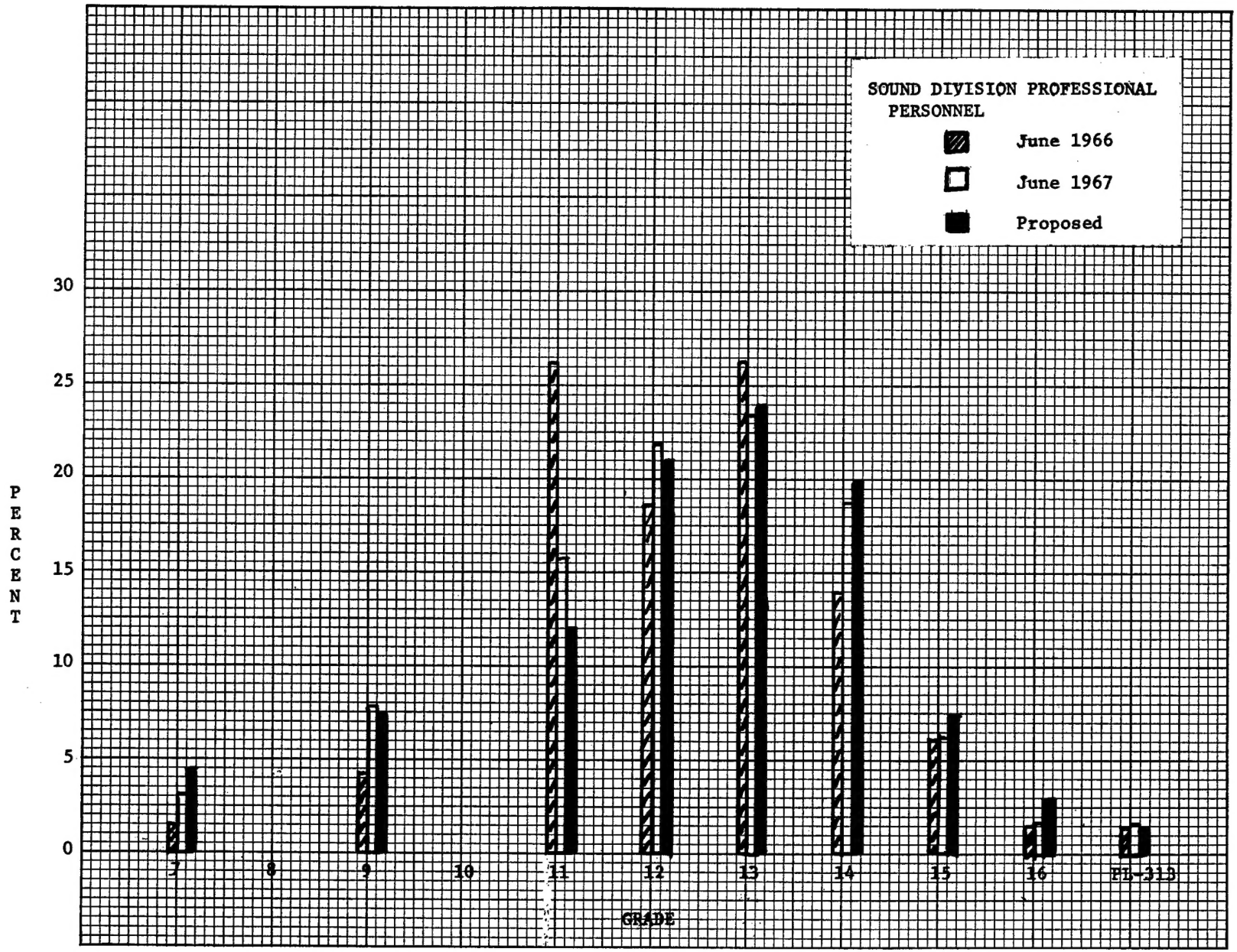

SOUND DIVISION PROFESSIONAL PERSONNEL
June 1966
June 1967
Proposed
PERCENT
30
25
20
15
10
5
0
7
8
9
10
11
12
13
14
15
16
FL-313
GRADE

Fig. 21

the Division has been hampered by this personnel ceiling. When ceilings were first established in the Laboratory, the Sound Division ceiling was 132. Successive cuts down to 112 caused curtailment of, and delays in the planned program. Recovery was incomplete at a level of 125 just before the shift of 5540 out of the Division. The five remaining branches of the Sound Division should be operating at an average level of about 20 per Branch. In addition, about 20 personnel are required for administration and to man facilities. Although the personnel ceiling has limited hires in the past, the Division has not been held to its ceiling in the past year. Many recruitment PAR's have been in for months but qualified candidates have not been found.

During the past year an attempt has been made to hire three Ph.Ds. All have received much higher offers, about $3,000 to $6,000 per year, from industry. Only one of them has chosen to come with us. A fourth Ph.D. has been approached and his decision is pending. The chances of acquiring him are poor.

The greatest need in the Sound Division is for theoretical physicists. If we are able to obtain Ph.D's at the 13 and 14 levels our grade average ceiling will be exceeded unless GS-7's and 9's can be hired to provide a balance.

A review of promotions in the Sound Division over the past two years shows an average of about one promotion per man in five years. There is some concern that resignations will rise at an alarming rate unless some relief can be afforded. A grade average ceiling of 11.20 would permit carrying out promotions listed in the staffing plan.

V. Funding

Fig. 22 shows the sources of funds in the past two years and anticipated for next year. In general, the FY-68 funding by NSSC is generous, and exceeds that of FY-67. ONR general funds have appeared particularly tight. One of the problems with which we are faced is retaining ONR funds when a problem supported by them is closed out, since closing out of a problem does not relieve the expenses associated with the personnel who must shift to another problem. Practically all Sound Division problems qualify for partial ONR funding on the basis of their being research.

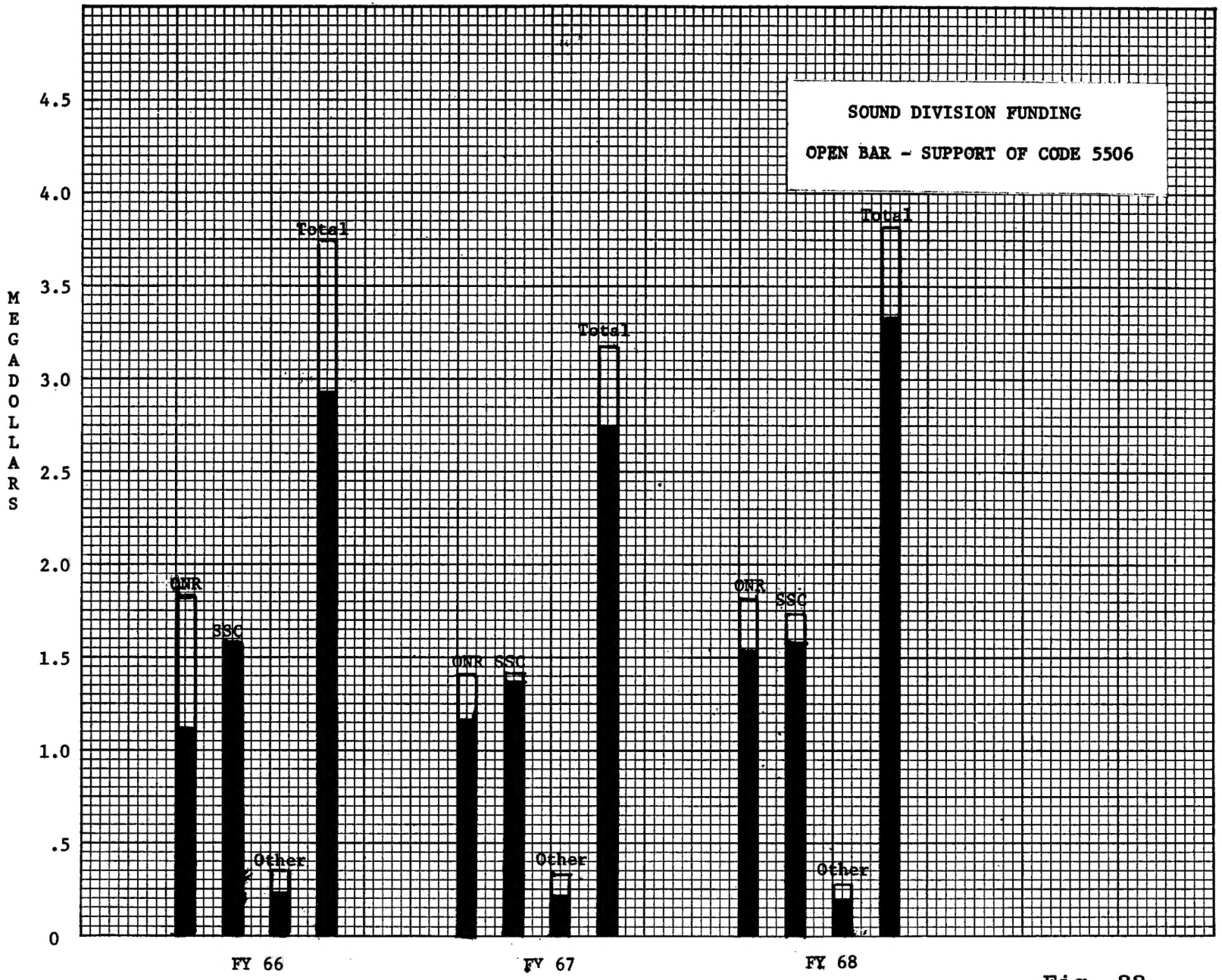

SOUND DIVISION FUNDING
OPEN BAR - SUPPORT OF CODE 5506
MEGADOLLARS
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
.5
0
Total
ONR
SSC
Other
FY 66
FY 67
FY 68

Fig. 22

VI. Publication Delays

It now takes up to a year to get a report published after it leaves the Branch. The letter report must be resorted to with a NRL report later having little utility except for record purposes. TID once claimed accomplishment of formal report publication in 30-odd days.

VII. At Sea Operations

There is now a prohibition against planned overtime. In field operations involving hard-to-get Navy ships services, it is necessary to plan to operate more than 8 hours per weekday - sometimes around the clock. If we do not, we would never be able to get any more services. There are not enough qualified people to operate 8 hour shifts, and even if there were, it would cost more than paying overtime. In at sea operations use of overtime must be scheduled. It is requested that policy be shaped accordingly.